Neural Associations through Mathematical and Contextual Connections

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Introduction

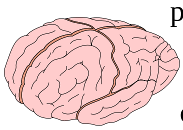
Upon reading standards documents, one often finds the word "connections," suggesting teachers need to "make or use connections." Many times we find arguments that we should make use of connections to make the math we teach "relevant." This likely isn't a bad reason, but relevant is a vague target. Neuroscience research has given us much clearer and more concise reasons. I would therefore like to propose a reason for using connections based in neuroscience research of basic brain function. I would argue that without knowing "why" we should make connections, the "how" may be misguided.

The Brain

There most certainly are educators who will claim the brain is too complicated for us to figure out how to capitalize on its function. With 100 billion neurons being excited/inhibited, with over 30 different neurotransmitter chemicals ebbing and flowing, with 100 trillion synapses connecting the neurons, neural networks constantly changing, neurons being created/dying, dendrites growing and fading, connections being pruned from lack of use or time, etc., one might understand this point of view. Others will say adapting brain function to education won't work because every brain is different. But if we accept this premise, we can make the same argument about students, thus nullifying educational research. Some will argue we do not know enough about how the brain works to apply neuroscientific research to education. Granted, modern brain science is only fifty, or so years old, but basing teaching practice on educational research is in its infancy, and this has not deterred the movement. The fact is that today we know enough about basic brain function to make wide-spread and immediate changes in **how** we teach mathematics.

Basic brain function is common to all brains. It is the brain that is capable of understanding what we teach. It is the brain that stores concepts and automates processes and procedures. It is the brain that recalls procedures and facts when needed. It is the brain that integrates stored ideas to create new ones. The list could go on, but, in this paper I will take a look at only one very small feature of basic brain function.

In this paper, I want to focus on memory and recall. To do this, we will address neural associations (educators refer to associations as connections). We will consider the use of associations as a process for developing a robust memory with better recall. HOWEVER, there are numerous actions we can take based on the instant-by-instant brain function to enhance memory. One of the most important functions of the brain is its innate ability to recognize patterns and to generalize them – this is a normal and constant function of the brain that is instrumental in creating a mental representation (or memory) of the generalizations. Another basic function is the brain's reaction to the enriched teaching environment. It promotes more correct recall. Two more are depth of processing and use of visualizations, ALL supported by research in the neurosciences. Timing during classroom presentations is also crucial to long-term memory, and this is related to the use of visualizations and contextual situations that lead directly to mathematical concepts. Most importantly, all of these ideas can be seamlessly integrated into the teaching process through a function approach implemented with a graphing calculator.



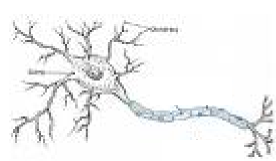
If you are wondering why I choose to focus on long-term memory, it is simple. About 30% of the recent high school graduates entering college must repeat high school algebra courses and many times even middle school mathematics before they are ready for college level math (college algebra). For those entering the two-year college system, the rate is over 50%. The sad downside of college students enrolling in remedial math courses is that only about 15% graduate (four-year college data). (Note: all Ohio data can be found at http://regents.ohio.gov/perfrpt/index.php under various "Performance Reports.) Finally, on recent EMPT tests (early math placement tests for college), the juniors UNDER-PERFORMED high school sophomores on 80% of the items based in the middle school curriculum. One of the likely reasons for all these issues is that fostering long-term memory of the mathematics that we teach is not a priority, or perhaps we have the mistaken notion that rote practice creates long-term memory. But mostly, we may not even be aware of how to create long-term memory of content we teach.

Associations

Without associations we quickly lose the ability to recall information/facts/procedures and to recall them correctly. What are associations? They are the connections among neural networks that can be created automatically by the brain when it learns something new. This was first discovered by Donald Hebb over 30 years ago. We commonly refer to his discovery as “neurons that fire together, wire together.” For example, suppose you want to create neural associations among the numeric, graphic, and symbolic representations of a function. It is extremely simple: graph a function on a graphing calculator and use trace (with expression turned on) to trace on the graph. This presents the brain with the simultaneous representations of a function causing the neural networks for the three representations to be associated. But if you never use the association again, it will soon be pruned. To understand why associations are important, read on, but it is mostly about correct long-term memory and recall.

Connections typically come in two forms: The first and most common form is to previously learned mathematics, but also, “New Information becomes more memorable if we ‘tag’ it [that is, associate it] with an emotion [like a familiar real-world context]” (Restak, 2006, p. 164). So we also need to connect new math concepts to contexts that are familiar (evoke an emotional response) to students. To create the neural associations, we simply present the mathematical concept and context simultaneously without adding fluff that distracts from the connection.

Associations are processed automatically in the brain, but what if in our normal teaching process, we have not made connections to related previous mathematics learned, or to understandable and familiar real-world contexts? This presents the brain with a problem. Why? Because “… the lower left part of the frontal lobe works especially hard when people elaborate on incoming information by associating it with what they already know” (Schacter, 2001, p. 25). Shouldn’t teachers make the connections so that the associations are appropriate and meaningful to the mathematics being taught? Here in lies the problem. Without teacher directed connections that are relevant to the concept/procedure being taught, the automatic associations made by each student’s brain will be different. Different may be OK, but it would seem more beneficial if students focused on a desired set of associations known to the teacher so that they could be drawn upon in future teaching.



Why are appropriate, relative, and common associations important? The answer is clear. “Memory recall almost always follows a pathway of associations. One [neural] pattern evokes the next pattern, which evokes the next pattern, and so on. … [E]ven though we have stored so many things, we can only remember a few at any time and can only do so in a sequence of associations” (Hawkins, 2004, pp. 71 & 73). Without appropriate associations, we see that memory recall may fail to produce desired results in the classroom.

There is more: It seems that not only does recall of information take a hit, so does understanding. That is, “We understand something new by relating it to something we’ve known or experienced in the past” (Restak, 2006, p. 164). Therefore, teaching without connections affects the understanding of what we are teaching. Moreover, neural associations are a necessary component of creative mathematical thought. “It has become a truism that the better connected a brain is, the better it is, period, enabling the mind it runs to connect new facts with old, to retrieve memories, and even to see links among seemingly disparate facts, the foundation for creativity" (Bagley, 2008, p. 69). Shouldn't we be in the business of developing creative minds as opposed to just creating good test takers?

Brains use associations and create them as a matter of normal operation – as shown by research in the neurosciences. It is the intent of this editorial to ask teachers to heed the call for the use of mathematical connections and familiar real-world contexts. The connections must flow smoothly and be appropriate to the new concepts being taught.

Cities and Roads

As the final part of this paper, I have included an adapted and abbreviated section from the book *Fast food education: Calling for a more natural approach to teaching & learning in America* (Taylor & Brock, 2008, pp. 55-61). The section is entitled "The Brain as A Road Map," and the book can be found at http://www.publishwithka.com/.

> The process of accessing and connecting information is something akin to our system of cities and roads connecting them. If you want to recall and use a fact (visit a city) it is most handy if there is a direct route to that city. Sometimes, however, there is no direct route and we have to go on many different roads to get there. The fewer roads that lead to any particular location, the harder it is for us to get there. Think of learning, then, as the process of construction. To know a fact for the first time, it must be built. In order to recall a fact/information, there must be a road going to that particular location. In the brain, these roads are called synaptic connections [neural networks]. Using a fact/info to solve a problem is equivalent to passing through a town on the way to somewhere else. For each fact then, it makes sense that there are two kinds of things that make that fact (city) more important, being useful, and/or being easy to use, that is:
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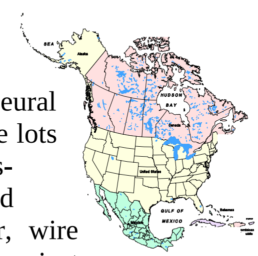
> • Have more roads that lead in and out of the city
> • Broadening the road and making it a faster highway



> The brain's equivalent to having more roads (synaptic connections) [neural networks] that lead into a particular town (fact/info) is to have the student make lots of connections with other facts that they know. We do this not by the stimulus-response lessons of Hunter and Gagne but by activating their old facts and experiences while we construct the new ones. [neurons that fire together, wire together.] The new fact becomes more of an extension of the old ones rather than just an added dot on the earth. The brain's equivalent to broadening the road (connection between facts) and making it a faster highway (quick recall) is to frequently use the connections. It is exactly like when a new trail is blazed through the wilderness. If it is never traveled again, the trail will quickly disappear with the vegetation along the trail filling in over it. If the path is frequented by travelers, it will not become overgrown. In fact, the more superhighways that lead to a particular fact, the quicker it will be to recall and apply that fact. This depiction emphasizes perhaps the most critical fact in academic achievement: it is not practicing a fact in isolation that makes it easy to recall and use, but it is using the connections it has to other facts that makes it so. In this same depiction, rote memorization is like placing the same city on the earth over and over without ever constructing a road that connects it to other important facts/cities.
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> This understanding of the brain dispels the lie that rote memorization is a good thing. This fits [Mark] Twain's definition of education ("Education is what is left when you forget all the facts that your teacher made you memorize when you where in school.") – We tend to forget things that we memorize without connections. Memorizing without understanding is like using a helicopter to fly in and establish cities in the middle of a jungle. When you have the helicopter, it is easy to revisit the spot. Once the helicopter has dropped you off back home, it will be incredibly difficult to travel back to the new cities by land. In a jungle with no roads, a trail must be cut through hard labor. If it is not paved the vegetation will soon grown back in and erase the trail. When this occurs in the

mind, there is no easy way to get back (recall) and you have a connection that is not going to stay as a connection.

The behaviorist model says let's learn this fact a bunch of times by practice, and then constant reviewing and re-teaching in the same stimulus-response mode suggests that students are basing the same knowledge on a different experience without connecting it to previously learned content. Students feel like they are starting from scratch in some cases. This creates another weak path. It is more confusing because they don't know which path to take.

After years of this, the teenage brainwash occurs - a chemical wash that breaks chemical connections in the brain. According to Dr. Jay Giedd of the National Institute of Mental Health, in the mid-teens, teenagers lose connections to a process called pruning in which the brain is restructuring. In an interview with PBS's Frontline, Dr. Geidd stated that, "Those cells and connections that are used will survive and flourish. Those cells and connections that are not used will wither and die." In other words, the brain is prioritizing and getting rid of extra connections. [An interesting aside: *"By one count, each cortical neuron forms, at the height of synaptogenesis, 15,000 connections: that works out to 1.8 million synapses per second from the second month in utero to the child's second birthday. Which synapses remain, and which wither away, depends on whether they carry any traffic. By one estimate, approximately 20 billion synapses are pruned every day between childhood and early adolescence."* (Schwartz & Begley, 2003, p. 117)] If you don't make each important path to knowledge a paved and well traveled road, then it will be washed out. The image of learning as road construction and use also dispels the notion that many teachers believe about the "dangers" of teaching more than one way to solve a problem. I have often heard teachers say that they will avoid discussing multiple solutions "because it will just confuse the students." But this may be because many students only know how to deal with facts (cities) and know precious little about how to connect and use those facts (roads).

Conclusion

Understanding what associations are, and how they can be created, should empower you to make connections in the teaching and learning of mathematics. What you will find in a function approach to the algebra curriculum is that the sole of the method is function representation and function behaviors that permeate throughout. Every concept taught is connected to function representation and/or function behavior. Most every concept is connected to a real-world context when introduced.

Without appropriate associations/connections, the brain has difficulty in long-term recall, so we have solid reasons for making them. In addition, as we teach mathematics making connections, we are teaching the brain to make associations. A brain that is better at making appropriate associations is a better brain. Shouldn't teaching align with how the brain works so we can create more useful brains for our students?

The product of continuous and integrated use of creating associations is long-term memory with correct recall. It suggests less review before the "big" test. It implies very limited review the first three weeks of a course. It means fewer remedial college math students.

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