Neuroscience and the Role of Pattern Generalizing in Algebra

- The brain's primary thinking mode is pattern generalizing; vision is dedicated to mathematical processing. So say Nobel Laureate Gerald Edelman and neuroscientist Steven Pinker. Where does reasoning fit? Sense making? Neuroscientists help here too.

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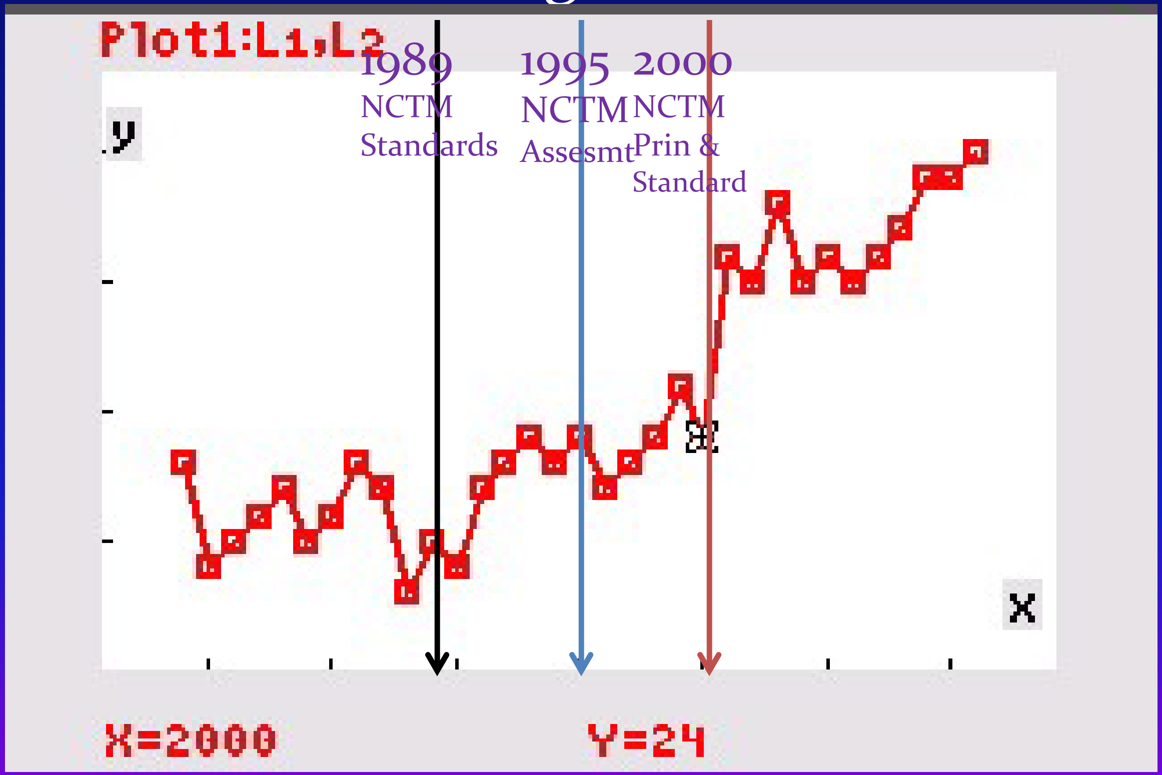
Stuff on my Mind

- "The mathematician takes ideas that are valid in one area and transplants them into another, hoping that they will take and not be rejected by the recipient domain." Alain Cannes, a mathematics professor at the *Institut des Hautes Etudes Scientifiques*

Tammet, D. (2012). *Thinking in numbers*, 269-270. Little, Brown and Company. New York.

Stuff on my Mind

- Remediation Rates of High School Students 1979-2011



Pattern Building in Teaching Generalizing in the Brain

- “When "connectionist" and other "neural network" models burst on the scene in the mid-1980s, they demonstrated learning capabilities and pattern-recognition powers that nobody would have dared postulate in small tracts of neurons a few years earlier.”

Dennett, D. C. (2013). *Intuition pumps and other tools for thinking*, 101. W.W. Norton & Company. New York.

Pattern Building in Teaching Generalizing in the Brain

- "… the brain's capacity to generalize [upon being presented with a pattern] is astonishing. … I have previously suggested that there are two main modes of thought-logic [reasoning] and pattern recognition. … the brain can function by pattern recognition even prior to language..."

  Edelman, G. M. (2004). *Wider than the sky: The phenomenal gift of consciousness*, 38-39, 47. Yale University Press. New Haven, CT.

- "For the most part we are not aware that we're constantly completing patterns, … If the patterns are related [developed] in such a way that the [brain] region can learn to predict what pattern will occur next, the cortical region forms a **persistent representation, or memory**, for the sequence."

  Hawkins, J. (2004). *On intelligence*, 74, 128. Times Books. New York.

Pattern Building in Teaching Generalizing in the Brain

- "Moreover, human brains operate fundamentally in terms of pattern recognition rather than logic."

Edelman, G. M. (2006). *Second nature: Brain science and human knowledge*, 83-84. Yale University Press. New Haven, CT.

- "The human mind is a pattern recognizer. The ability to see patterns and similarities is one of the greatest strengths of the human mind."

Devlin, K. (2010). The mathematical brain. In D. A. Sousa (Ed.), *Mind, brain, & education: Neuroscience implications for the classroom*, 169. Solution Tree Press. Bloomington, IN.

Pattern Building in Teaching Generalizing in the Brain

- "… unconscious pattern recognition contains a calculation of probability of correctness, which is consciously experienced as a *feeling of knowing*. The closer the fit between previously learned patterns and the new incoming pattern, the greater the degree of the *feeling of correctness* will be."

Burton, R. A. (2008). *On being certain: Believing you are right even when you're not,* 135. St. Martin's Press. New York.

Pattern Building in Teaching Generalizing in the Brain

- "The increased dopamine release in response to the satisfaction of a correct response reinforces the memory of the information used to answer the question, make a prediction, or solve a problem. The brain favors and repeats actions that release more dopamine, so the involved neural memory circuits becomes stronger and is favored when making similar future choices."

Willis, J. (2010). The current impact of neuroscience on teaching and learning. In D. A. Sousa (Ed.), *Mind, brain, & education: Neuroscience implications for the classroom* (pp. 44-66). Bloomington, IN. Solution Tree Press.

Pattern Building in Teaching Generalizing in the Brain

- “Ideas [concepts] gain the power of rewards and become instantly meaningful to the rest of the brain, especially the learning and decision-making algorithms running there.”

Montague, R. (2007). Your brain is (almost) perfect: How we make decisions, 111. New York: Plume.

Pattern Building in Teaching Generalizing in the Brain

- "Evolution favors pattern seeking, because it allows the possibility of reducing mysteries to fast and efficient programs in the neural circuitry."

  Eagleman, D. M. (2011). *Incognito*: *The secret lives of the brain*, 139. Pantheon Books, NY.

- "The building blocks of the brain ensure that it is highly adept at recognizing patterns, but poorly prepared for performing numerical calculations."

  Buonomano, D. (2011). *Brain bugs: How the brain's flaws shape our lives*, 224. W. W. Norton & Company, NY.

Pattern Building in Teaching Generalizing in the Brain

- "It [pattern generalizing] is enormously powerful, but because of the need for range, it carries with it a loss of specificity."

HOWEVER…

- "the use of controlled scientific observation enormously enhances the specificity and generality of these interactions."

Edelman, G. M. (2006). *Second nature: Brain science and human knowledge*, 83, 103-104. Yale University Press. New Haven, CT.

Visualizations

- "… because we have visual, novelty-loving brains, we're entranced by electronic media."

Ackerman, D. (2004). *An alchemy of mind: The marvel and mystery of the brain*, 157. Schibner. New York.

Visualizations

- "Mathematical reasoning both takes from and gives to the other parts of the mind. Thanks to graphs, we primates grasp [understand] mathematics with our eyes and our mind's eye. So, vision was co-opted for mathematical thinking, which helps us see [**understand**] the world."

  Pinker, S. (1997). *How the mind works*, 359-360. W. W. Norton & Company. New York.

- "It seems that when people are actually doing math, they use brain regions that also do spatial processing."

  Bergen, B. K. (2012). *Louder than words: The new science of how the mind makes meaning*, 255. Basic Books. New York.

Visualizations

- "… after studying pictures along with the words, participants expect **more from their memories**. They easily **reject items** that do not contain the distinctive pictorial information they [brains] are seeking …"

  Schacter, D. L. (2001). *The seven sins of memory: How the mind forgets and remembers*, 103. Houghton Mifflin Company. Boston.

- "Professor Leo Standing, a Canadian psychologist, [asked psychology students to view 100 pictures for 5 seconds each] … He brought them back in a week, and showed them the pictures again, mixed with 100 new pictures, … The students correctly recognized more than 90% of the pictures, having seen them only once, for just five seconds. [The same 90% results were returned for 1,000 pictures, and then for 10,000.]"

  Lynch, G. & Granger, R. (2008). *Big brain: The origins and future of human intelligence*, 158. Palgrave McMillan. NY.

Visualizations

- "Advocates of dual coding theory argue that people retain information best when it is encoded in both visual and verbal codes."

Byrnes, J. P., (2001). *Minds, brains and learning: Understanding the psychological and educational relevance of neuroscientific research*, 51-52. The Guilford Press. New York.

Understanding/Meaning
Neural Associations

- "**We understand** something new by relating [associating] it to something we've known or experienced in the past."

Restak, R. (2006). *The naked brain*, 164. Three Rivers Press. NY.

- "...abstract concepts are understood in terms of concrete ones..."

Bergen, B. K. (2012). *Louder than words: The new science of how the mind makes meaning*, 214-216. Basic Books. New York.

Understanding/Meaning Formative Assessment

- "We know that understanding increases with corrective feedback after the brain makes incorrect predictions. Frequent formative assessment and corrective feedback are powerful tools to promote long-term memory and develop the executive functions of reasoning and analysis."

Willis, J. (2010). The current impact of neuroscience on teaching and learning. In *Mind, brain, & education: Neuroscience implications for the classroom,* 56. Bloomington, IN. Solution Tree Press.

Understanding/Meaning
Contextual Situations

- "When a child has a personal stake in the task, he can reason about that issue at a higher level than other issues where there isn't the personal stake. … These emotional stakes enable us all to understand certain concepts more quickly. … understanding concepts involves a sequence of steps that begins with emotional interactions."

Greenspan, S. I. & Shanker, S. G. (2004). *The first idea: How symbols, language, and intelligence evolved from our primate ancestors to modern humans*, 241-2. Da Capo Press. Cambridge, MA.

Understanding/Meaning
Teacher-Student Differences

- "Expertise affects the detail with which people understand [mathematical] language.

- ... the brains of experts and novices respond differently to language about a particular activity: experts activate brain areas responsible for controlling well-learned actions more, while novices activate primary senses and motor areas more."

Bergen, B. K. (2012). *Louder than words: The new science of how the mind makes meaning*, 155-157. Basic Books. New York.