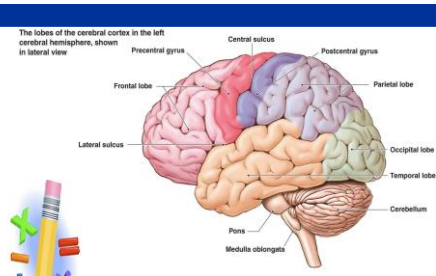
The Neuropsychology of Mathematics: Module #5



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Course Outline: Module #5

- Six part webinar series on reading, writing, & math disabilities sponsored by Jack Hirose & Associates.
- Introduce a brain-based educational model of dyslexia, dysgraphia, and dyscalculia and classify each disability into distinct subtypes.
- Discuss targeted interventions for all students with academic learning issues.
- Questions and Comments?

- **Steven G. Feifer, D.Ed., ABSNP**
  - 2008 MD School Psych of Year
  - 2009 NASP School Psych of Year
  - Authored 7 books
  - Authored 2 tests: FAR & FAM
  - feifer@comcast.net

Presentation Of Goals

(1) Discuss the international trends in math, and reasons why the United States and Canada lag behind other industrialized nations in math and science.

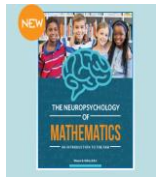
(2) Explore the role of various cognitive constructs including working memory, visual-spatial functioning, language, and executive functioning, with respect to math problem solving ability.

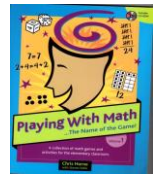
(3) Discuss three subtypes of math disabilities, and specific remediation strategies for each type.

(4) Discuss the main neural pathways that contribute to the development of number sense and quantitative reasoning.

(5) Introduce the Fam, a diagnostic test of mathematics designed to examine the underlying neuro-developmental processes that support the acquisition of proficient math skills.

Future Reading Materials





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2015 NAEP DATA: 4th & 8th

http://www.nationsreportcard.gov/reading_math_2015/#?grade=4

Content items: overlap with common core (adopted by 43 states)

a) **Number properties and operations** measures students' understanding of ways to represent, calculate, and estimate.

b) **Measurement** assesses students' knowledge of measurement for such attributes as capacity, length, area, volume, time, and angles.

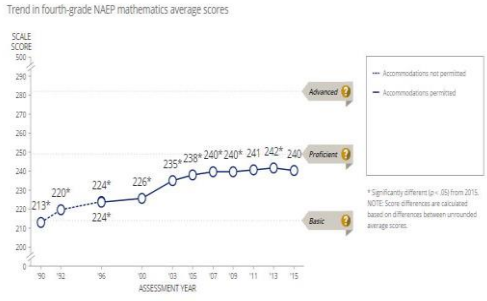
c) **Geometry** measures students' knowledge and understanding of shapes in two and three dimensions and relationships between shapes such as symmetry and transformations.

d) **Data analysis, statistics, and probability** measures students' understanding of data representation, characteristics of data sets, experiments and samples and probability.

e) **Algebra** measures students' understanding of patterns, using variables, algebraic representation, and functions.

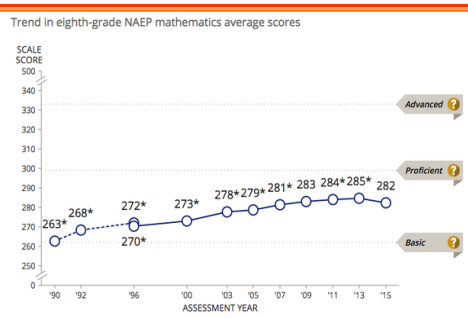
*** Survey taken every 2 years.**

2015 NAEP DATA: 4th grade



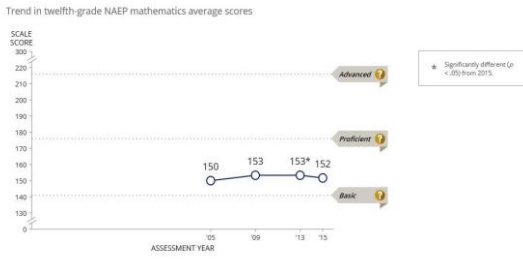
***40% of 4th graders at or above a Proficient level in mathematics (n=279,000 public and private)**

2015 NAEP DATA: 8th grade



***33% of 8th graders at or above a Proficient level in mathematics (n=273,000 public and private)**

2015 NAEP DATA: 12th grade



***25% of 12th graders at or above a Proficient level in mathematics (13,200 students participated)**

PISA DATA (2015): 15 yr. olds

(Program for International Student Assessment)

OECD (2017), Mathematics performance (PISA) (indicator). doi: 10.1787/04711c74-en (Accessed on 09 January 2017)

* A test of mathematical literacy for ***15*** year old students which focuses upon the direct application of mathematical principles. The test is administered every three years.

* Approximately 540,000 students completed the assessment in 2015, representing **72** participating countries**.**

* The test was ***not*** designed to measure curricular outcomes, but rather to assess mathematics' literacy within a real world context.

Student Selection:

- PISA international contractors sampled schools in each country according to strict technical standards.
- Must have 6 years of formal education in private, public, or vocational school.
- Less than 4% of schools excluded. Criteria included intellectual disabilities or insufficient language experiences.
- Science was featured subject in 2015.

PISA DATA (2015): 15 yr. olds
(Program for International Student Assessment)

Content Samples:

- **Change and relationship**: Can students model change and relationships with the appropriate functions and equations?
- **Space and shape:** Can students understand perspective, create and read maps, and manipulate 3D objects?
- **Quantity:** Are 15-year-olds able to comprehend multiple representations of numbers, engage in mental calculation, employ estimation, and assess the reasonableness of results?
- **Uncertainty and data:** Can students use probability and statistics and other techniques of data representation and description to mathematically describe, model, and interpret uncertainty?

PISA DATA (2015): 15 yr. olds
(Program for International Student Assessment)

RESULTS:

- In 2015, the average U.S. score in mathematics literacy was **470**, lower than the international average score of **490** by **20** points.
- In 2012, the average U.S. score in mathematics was **481**, indicating an **11** point drop in performance from 2015.
- In 2009, the average U.S. score was **487**, indicating a **17** point drop in performance from 2015.
- Among the **72** countries in the 2015 PISA sample, the U.S. was statistically outperformed by **36** countries.
- The U.S. average Science score was **496**, which was ahead of the international average of **493**, and higher than all but **18** countries who participated in the 2015 PISA study.

PISA DATA (2015): 15 yr. olds

Country	Average Score
International Average	490
1. Singapore	564
2. Hong Kong-China	548
3. Macao-China	544
4. Taiwan	542
5. Japan	532
6. B-S-J-G China (Beijing, Shanghai, Jiangsu, and Guangdong)	531
7. Korea	524
8. Switzerland	521
9. Estonia	520
10. Canada	516
11. Netherlands	512
12. Denmark	511
13. Finland	511
14. Slovenia	510
15. Belgium	507
16. Germany	506
17. Poland	504
18. Ireland	504
19. Norway	502

PISA DATA (2015): 15 yr. olds

Country	Average Score
International Average	490
20. Austria	497
21. New Zealand	495
22. Vietnam	495
23. Russian Federation	494
24. Sweden	494
25. Australia	494
26. France	493
27. United Kingdom	492
28. Czech Republic	492
29. Portugal	492
30. Italy	490
31. Iceland	488
32. Spain	486
33. Luxembourg	486
34. Latvia	482
35. Malta	479
36. Lithuania	478

PISA DATA (2015): 15 yr. olds

Country	Average Score
International Average	490
37. Hungary	477
38. Slovak Republic	475
39. Israel	470
40. UNITED STATES	470
41. Croatia	464
42. Kazakhstan	460
43. Buenos Aires	456
44. Greece	454
45. Malaysia	446
46. Romania	444
47. Bulgaria	441
48. Cyprus	437
49. United Arab Emirates	427
50. Chile	423
72. Dominican Republic	328

PISA DATA (2012): Canadian Decline

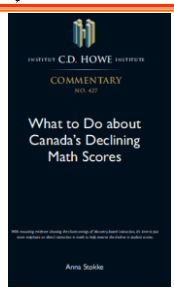
PISA 2003-2012 – Results in paper-based mathematics – Canada and provinces

	2003		2006		2009		2012	
	Average	S.E.	Average	S.E. with linking error*	Average	S.E. with linking error*	Average	S.E. with linking error*
Canada	532	1.8	527	2.4	527	2.6	**518**	2.7
Newfoundland and Labrador	517	2.5	**507**	2.8	**503**	3.4	**490**	4.2
Prince Edward Island	500	2	501	2.7	**487**	3.0	**479**	3.2
Nova Scotia	515	2.2	**506**	2.7	512	3.0	**497**	4.5
New Brunswick	512	1.8	506	2.5	**504**	3.0	**502**	3.2
Quebec	537	4.7	540	4.4	543	3.9	536	3.9
Ontario	530	3.6	526	3.9	526	3.8	**514**	4.5
Manitoba	528	3.1	521	3.6	**501**	4.1	**492**	3.5
Saskatchewan	516	3.9	507	3.6	506	3.8	506	3.6
Alberta	549	4.3	**530**	4.0	**529**	4.8	**517**	5.0
British Columbia	538	2.4	**523**	4.6	**523**	5.0	**522**	4.8

Results in bold indicate a statistically significant difference compared with the baseline (2003).
* The standard error of measurement includes a linking error to account for the comparison of results over time between the baseline (2003) and subsequent years.

Anna Stoke (May, 2015)

Associate Professor of Mathematics and Statistics at University of Winnipeg

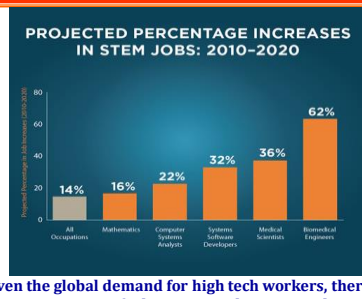


1. **Employ the 80/20 rule for direct instruction to discovery based learning.**
2. **Reduce multiple strategy approaches that are inefficient and place too much burden on working memory.**
3. **Important concepts are introduced too late, especially Algebra.**
4. **Teacher training in mathematics needs to improve.**

GROUP DISCUSSION ACTIVITY

- **What are possible reasons for Canada's decline?**
- **Do you agree with Anna Stoke's recommendations?**
- **How many instructional minutes are devoted toward mathematics vs. language arts in the curriculum?**

The STEM Initiatives



- **Given the global demand for high tech workers, there is a greater exportation of jobs overseas due to a combination of cheaper wages, as well as a better educated workforce in mathematics and science.**

4 Reasons for U.S Decline

1. Time on task. Most elementary math instruction occurs in the afternoon, average is 54 instructional minutes per day (89 min language arts).
2. Dry and boring material. Mathematical skill building needs to be FUN, and therefore needs to be presented in the format of games and activities.
3. Too much focus on the answers. In order to develop conceptual understanding, students should practice multiple methods of problem solving from both a visual-spatial and verbal approach.
4. Teacher Training. Nearly half of elementary education majors have difficulty themselves with a variety of basic math skills (Murphy et al., 2011)

What is a Math Disability?

*Dyscalculia – children with specific math-related deficits, including : a) Learning and retrieving mathematical facts
(Language Retrieval)
b) Executing math calculation procedures
(Working Memory)
c) Basic number sense and concept development
(Executive Functioning)

Math Learning Disability (MLD) - a generic term referring to children whose math performance in the classroom is substantially below age- and grade-level expectations. Often used when there is unexpected underachievement.

* Up to 20% of school age children have MLD or persistent difficulty with math (Iuculano et al., 2015)

The "MLD" Profile
(Geary, 2011: Rasanen, et al., 2009)

1. Are slower in basic numeric processing tasks:
   - Rapidly identifying numbers.
   - Making comparisons between magnitude of numbers.
   - Counting forwards and backwards
2. Struggle in determining quantitative meaning of numbers:
   - Poor use of strategies.
   - Do not visualize numbers well.
3. Have difficulty learning basic calculation procedures needed to problem solve.

The "MLD" Profile
(Geary, 2011: Rasanen, et al., 2009)

MLD Error Profile:

- Prone to procedural errors such as saying "5,6,7" when solving 5 + 3 = ___
- Misalign numbers:
  36
  +3
  66
- Fail to borrow in a sequential manner:
  83
  - 44
  41
- Often deploy the wrong computational process: "The school store sold twice as many pencils to Sam than Robert. If Sam was sold four pencils, how many pencils were sold to Robert?" 8
- Poor retrieval of basic facts: 7 X 6 = 35

The Neural Machinery of Mathematics

Language Skills: (temporal lobes)

- Most Asian languages have linguistic counting systems past *ten* (*ten-one, ten-two, etc)* whereas English deviates from base-10 system (Campbell & Xue, 2001).
- In English counting system, decades come first then unit *(i.e. twenty-one)* or sometimes this is reversed *(i.e. fifteen, sixteen, etc…)*
- Chinese numbers are brief *(i.e. 4=si, 7=qi)* allowing for more efficient memory. By age four, Chinese students can count to 40, U.S. students to 15.
- U.S. kids spend 180 days in school
  South Korea children spend 220 days in school
  Japan kids spends 243 days in school

The Neural Machinery of Mathematics

Language Skills: (temporal lobes)

- Early math skills tend to be verbally encoded, and that is how we initially learn math facts.
- Children with math disabilities frequently have delays in their language development (Shalev et al., 2000)
- Word problems offer an intricate relationship between language and mathematics. Terms such as *all, some, neither, sum, etc.* may be confusing when embedded in the grammatical complexity of word problems (Levine & Reed, 1999).

The Neural Machinery of Mathematics

Working Memory Skills: (Baddeley,1998)

- ***Phonological Loop*** - holds and manipulates acoustic information. Housed in *left temporal lobes.*
- ***Visual-Spatial Sketchpad*** - holds visual, spatial, and kinesthetic information in temporary storage by way of mental imagery. Housed along inferior portions of *right parietal lobes.*
- ***Central Executive System*** - command post for controlling two slave systems. Allocates attention resources whereby two cognitive tasks can be executed. Primarily housed in *frontal lobes.*
  - Central executive system serves to inhibit any negative distracters when problem solving (Hopko, 1998).

Horizontal Vs. Vertical
(Trbovich & LeFevre, 2003).

- Solving problems in a vertical format required the use of more visual resources, particularly the visual-spatial sketchpad of working memory.
- Solving problems in a horizontal format required more phonological resources resulting in ***slower*** performance.

A 32 + 6	B 6 + 32
C 32 + 6	D 6 + 32

Working Memory In The Brain

Working Memory System	Mathematical Skill
• *Phonological Loop*	• *Retrieval of math facts* • *Writing dictated numbers*
• *Visual-Spatial Sketchpad*	• *Mental math* • *Magnitude comparisons* • *Geometric Proofs*
• *Central Executive System*	• Inhibiting distracting thoughts • Modulating anxiety • Regulating emotional distress.

Interventions for Lower Working Memory

- Number-line situated on student's desk.
- Use a calculator.
- Increase number sense through games such as dice, domino's, cards, etc..
- Encourage paper and pencil use while calculating equations.
- Use mnemonic techniques to teach math algorithm's and sequential steps to problem solving (i.e. The steps for long division are
  Divide, Multiply, Subtract, Bring Down:
  Dad Mom Sister Brother
  Dead Monkies Smell Bad
- Reduce anxiety in the classroom.

Math Anxiety

Cortisol – a glucocorticoid (glucose-cortex-steroid) that regulates the metabolism of glucose in the brain. A balance or homeostasis of cortisol is needed for optimal brain functioning. Too much *(Cushing's Syndrome)*...too little *(Addison's Disease)*.

- Anxiety primes our memory system by facilitating the initial encoding and registration of memory, as well as retrieval of long term memory (Wirth, 2015).
- Anxiety impacts cognition and learning by way of working memory (Dowker et al., 2015)

The Truth About Math Anxiety: Do We Have a Math Phobia?

Implicit Messages:

"Oh not to worry Billy, I was never that good in math either."
"Wow, are you taking Algebra II....that is sooooo hard!"
"Hey Ritchie...it doesn't matter if you do not understand your math homework, you will never use this stuff in real life."

CAUSES OF MATH ANXIETY:

- Timed tests
- Pop quizzes
- Being called upon to write a math problem on the board
- Speeded skill drills and classroom competitions
- Teaching too quickly before concepts are consolidated
- Unit tests that cover too much information
- No visual cues
- Poor instruction
- Classroom climates that prevent students from asking questions
- Stressing teacher's own algorithm

The Truth About Math Anxiety: Do We Have a Math Phobia?

*According to the Office of Economic Development (2013), 59% of 15 yr olds taking the PISA Test often worry about math, and 30% feel helpless when executing a problem.

- Teachers who have math anxiety tend to impact girls' math performance more than boys (Beilock et al., 2010). Similar findings with mothers and daughter dyads (Casad et al., 2015).
- Glaring weakness in research is which type of math skill impacted most by anxiety (Dowker et al., 2016).

GROUP DISCUSSION ACTIVITY

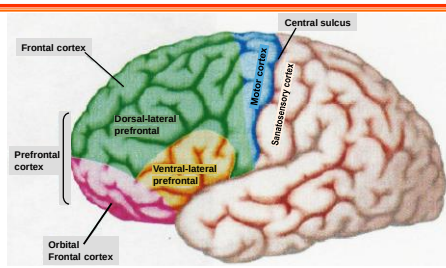
- What are some ways teachers and parents can help reduce math anxiety?
- What changes would you like to see to the curriculum to help reduce math anxiety?
- Do you feel that using calculators would help reduce math anxiety?

The Neural Machinery of Mathematics

Executive Functioning Skills: (frontal lobes)

- Executive control mechanisms are a set of directive processes such as planning, self-monitoring, organizing, and allocating attention resources to effectively execute a goal directed task.
- Executive functioning dictates "*what to do when*", a critical process in solving word problems.
- Executive functioning allows students to choose an appropriate algorithm when problem solving.

The Neural Machinery of Mathematics



The Neural Machinery of Mathematics

EXECUTIVE DYSFUNCTION	BRAIN REGION	MATH SKILL
• *Selective Attention*	• *Anterior Cingulate/* • *Subcortical structures*	• Poor attention to math operational signs • Place value mis-aligned
• *Planning Skills*	• *Dorsal-lateral PFC*	• Selection of math process impaired • Difficulty determining salient information in word problems

The Neural Machinery of Mathematics

EXECUTIVE DYSFUNCTION	BRAIN REGION	MATH SKILL
• *Organization Skills*	• *Dorsal-lateral PFC*	• Inconsistent lining up math equations • Frequent erasers • Difficulty setting up problems
• *Self-Monitoring*	• *Dorsal-lateral PFC*	• Limited double-checking of work • Unaware of plausibility to a response.

Building a Math Brain: 4 Neurocognitive Factors

1. Approximate Number System - non-symbolic representation of math represented by space and time.
2. Connectivity - linking non-symbolic representations with symbolic representations (numerals) to form our own internal number line.
3. Automaticity - facts and procedures.
4. Quantitative knowledge - mathematical reasoning emerges from the development of *number-sense* as students learn to apply mathematics to real world problems.

Let's Stay Connected!

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Tests: Feifer Assessment Mathematics
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