With STEM in Mind:

How the New Science of the Brain is Changing STEM Education

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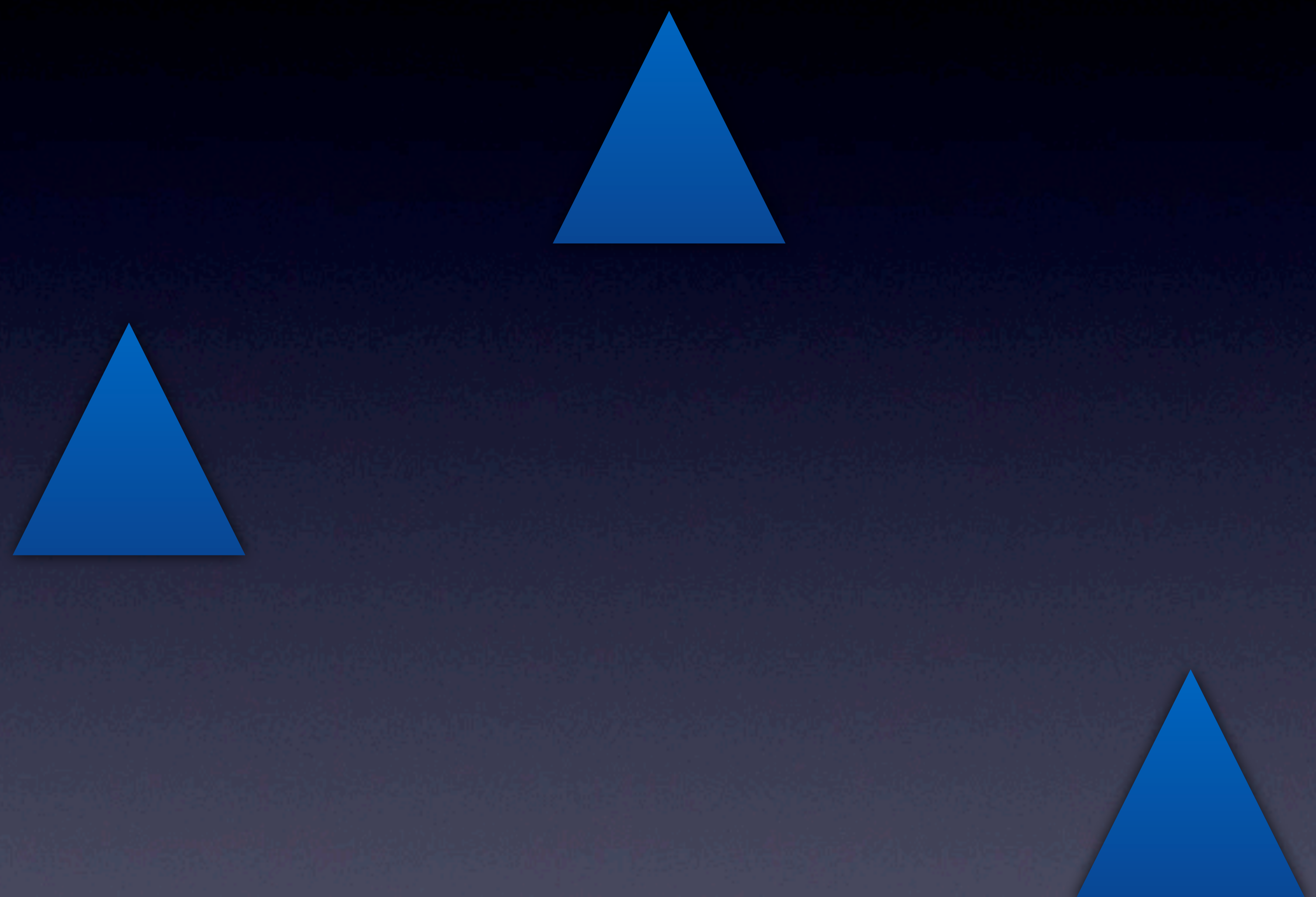
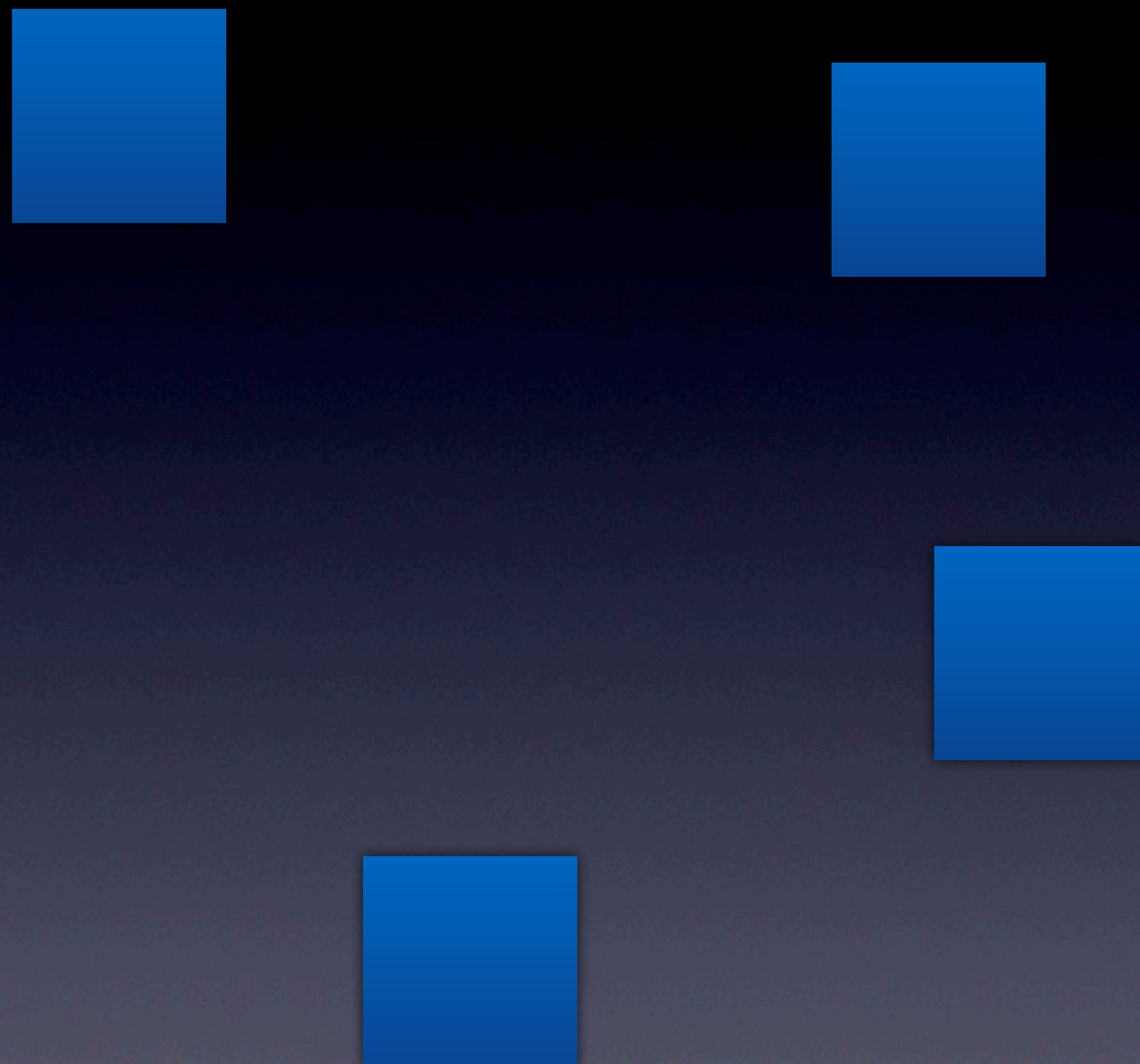
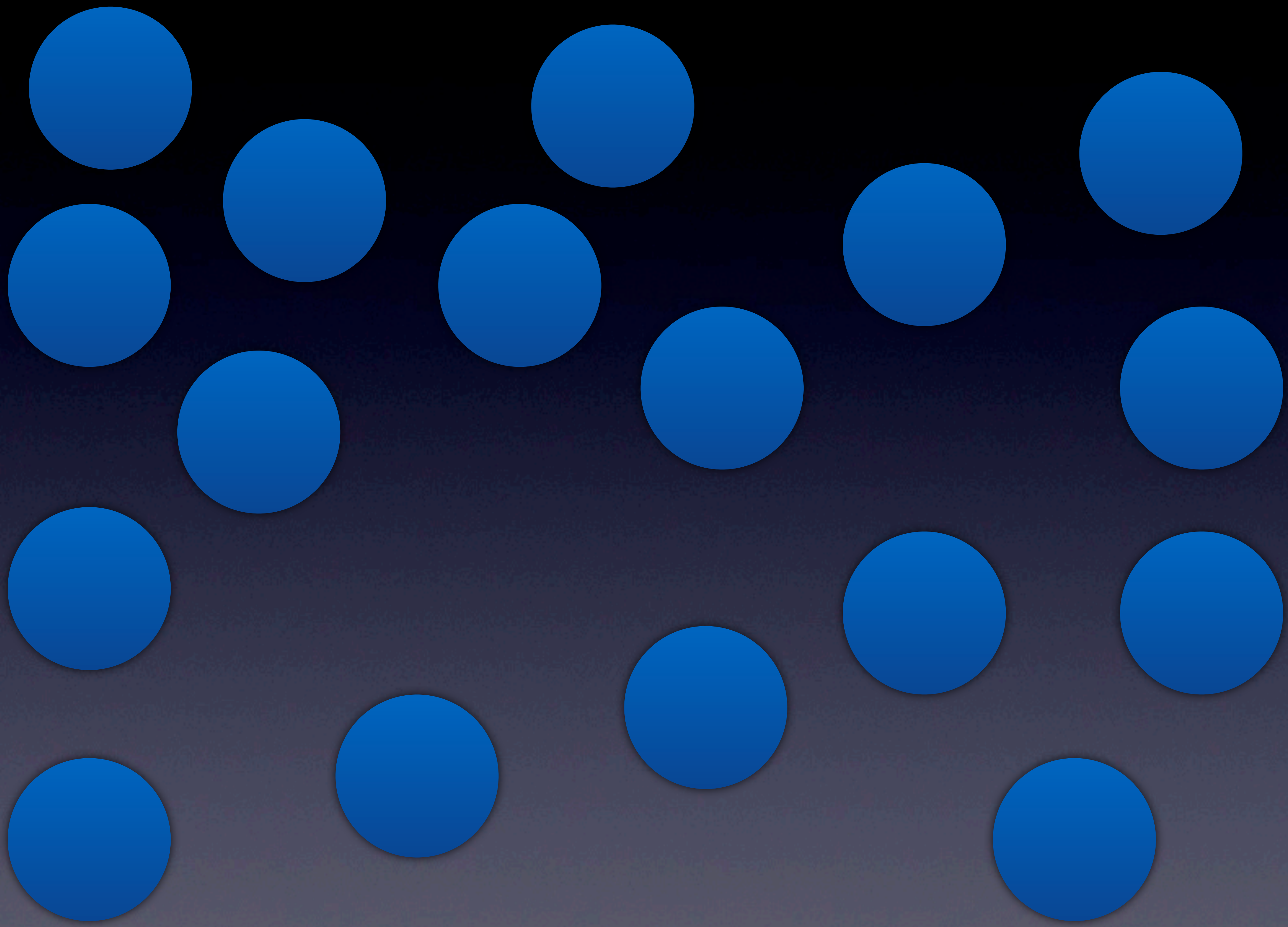
An Activity





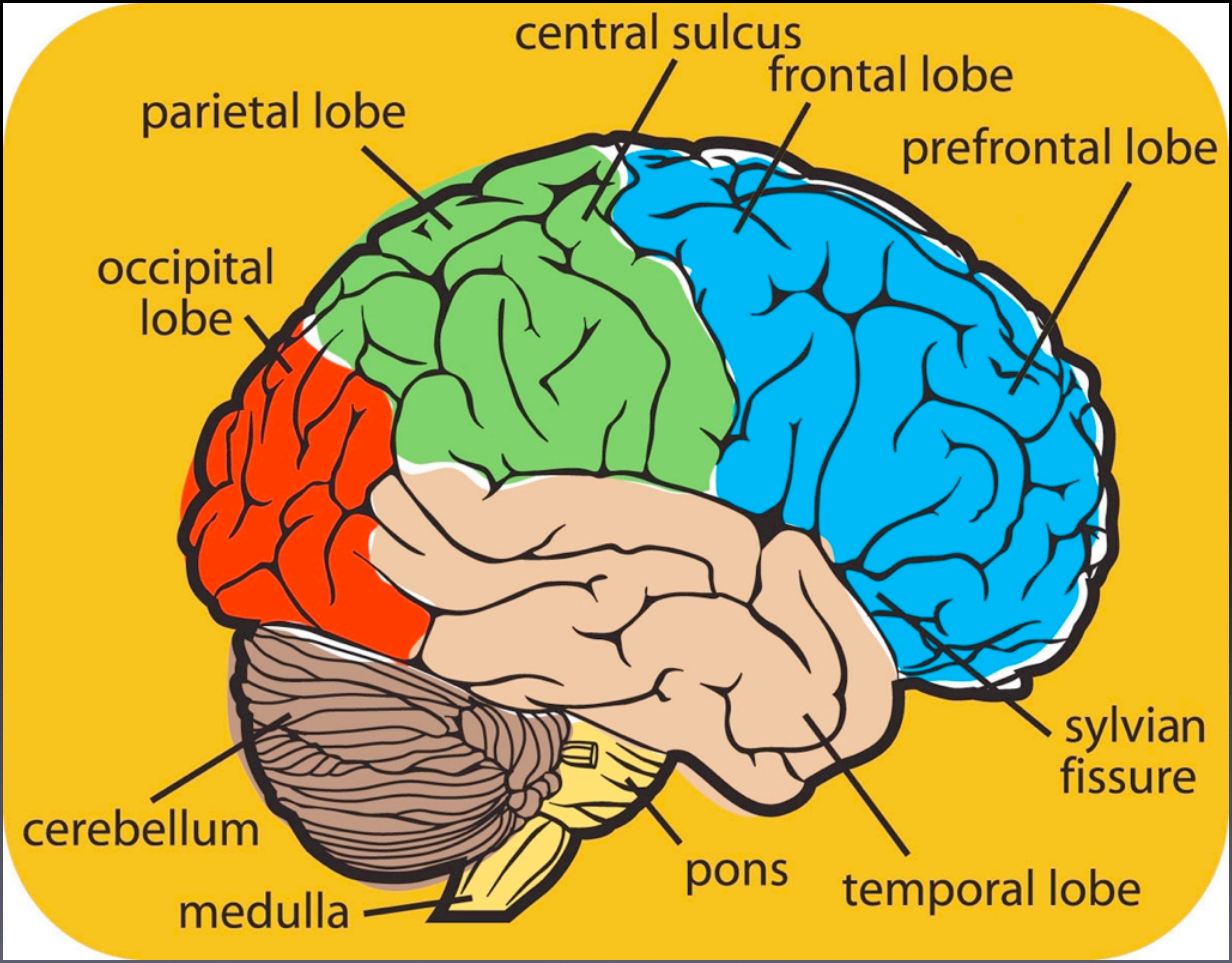


What happened?

The task changed from **perception** to **computation**

This is an example of **number sense**

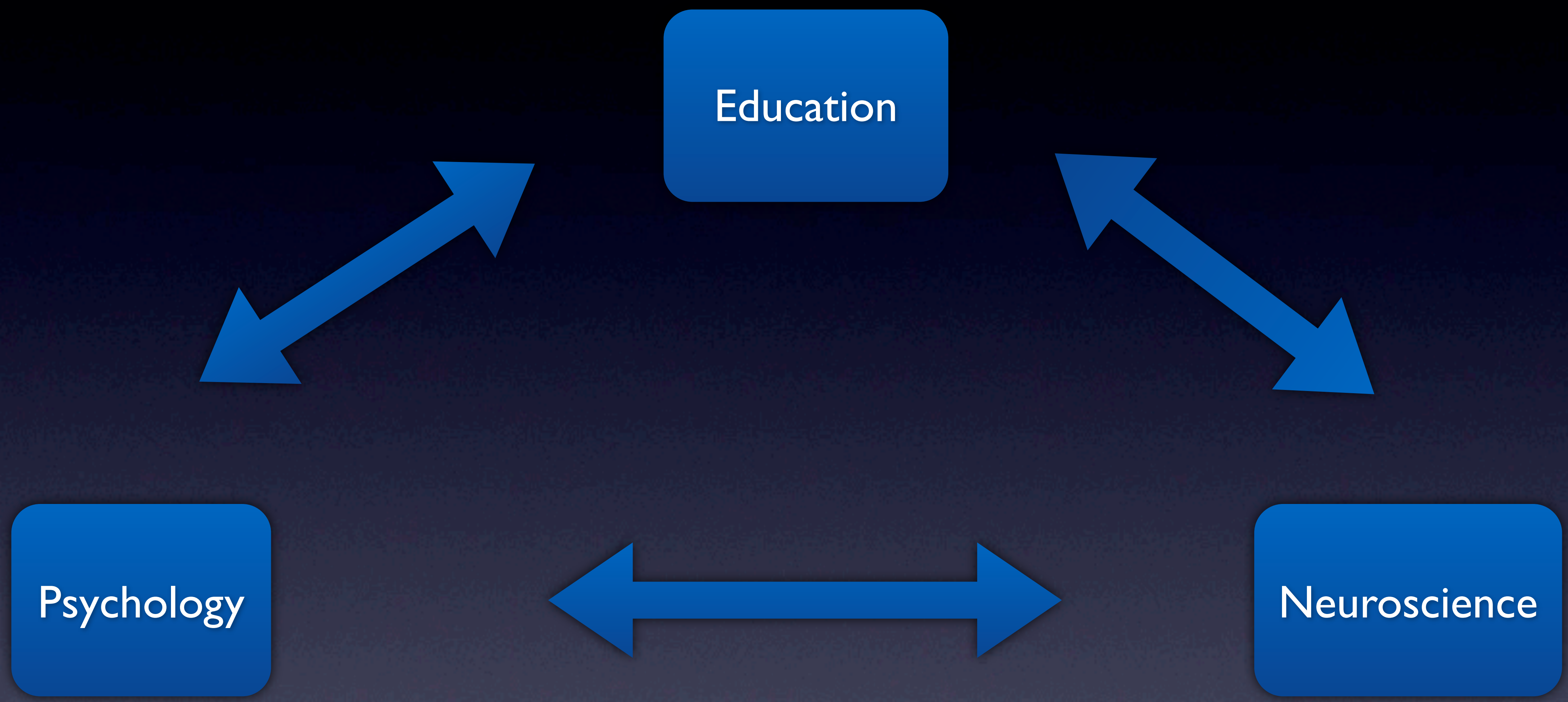
(**Subitizing**, to be exact)


central sulcus
frontal lobe
parietal lobe
prefrontal lobe
occipital lobe
sylvian fissure
cerebellum
pons
temporal lobe
medulla

What's the point?

Typically developed brains share many cognitive characteristics. They tend to work in very similar ways.

Brain science posits that understanding the fundamental ways in which our brains work can help us become better learners and better educators.


Education
Psychology
Neuroscience

Education	Individual learning
Psychology	Cognition and behavior
Neuroscience	Neural substrates of cognition

My goal today is to offer advice for STEM educators grounded in findings from brain science research.

Due to time constraints, I will gloss over sources and methods.

Neuroscience research in particular requires careful study.

To download these slides and a list of references and further reading:

mgsaldivar.com

What will we discuss?

- Common myths about the brain
- Findings from STEM-related brain research
- Pedagogical implications

Common myths about the brain

“Some students will never learn ____ because of race (or gender) (or linguistic background) (or ____).”

“If you don’t learn ____ by age ___ then you will never learn it.”

“We only use ___% of our brains.”

“______ is very difficult to learn if you are (left-brained) (right-brained).”

Findings from STEM Education

Conceptual understanding of math involves both language and mathematical cognition

Example:

3 vs *three* vs *III* vs 

Different parts of the brain process these different representations of *three*

Source: Stanislas Dehaene

Basic addition and subtraction are
perceptual processes.

Multiplication and division are
computational processes.

Algebra and higher math involve abstraction.

DISCUSS: ‘Three-ness’

	January February March	GPA = 4.0 GPA = 3.0 GPA = 2.0

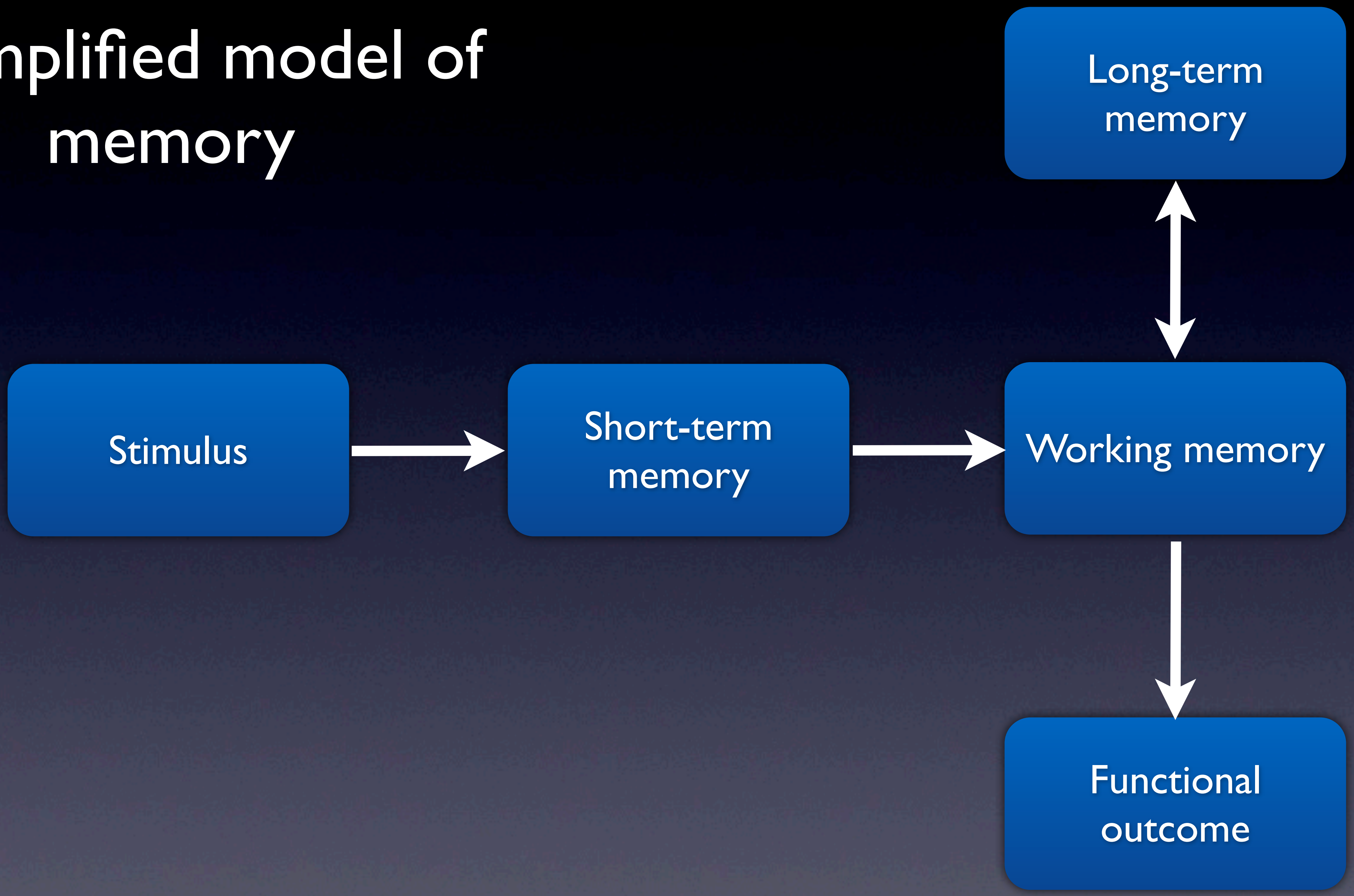
Mathematical problem-solving seems to involve one of two strategies:

Memory retrieval	*Procedural*
“The answer popped into my head.”	“I broke the problem down into ___ steps.”

Source: Daniel Ansari

Memory retrieval involves **working memory.**

A simplified model of memory



Recalling an existing memory is more efficient than embarking on a new round of abstract thinking (such as computation).

Our brains default to algorithmic processes called **heuristics.**

A heuristic is a mental shortcut comprising a set of instructions or steps, like a computer program.

Heuristics are typically procedural in nature.

There is a close relationship between our knowledge of the natural world and our ability to evaluate scientific (and mathematical) concepts.

Source: Duschl et. al.

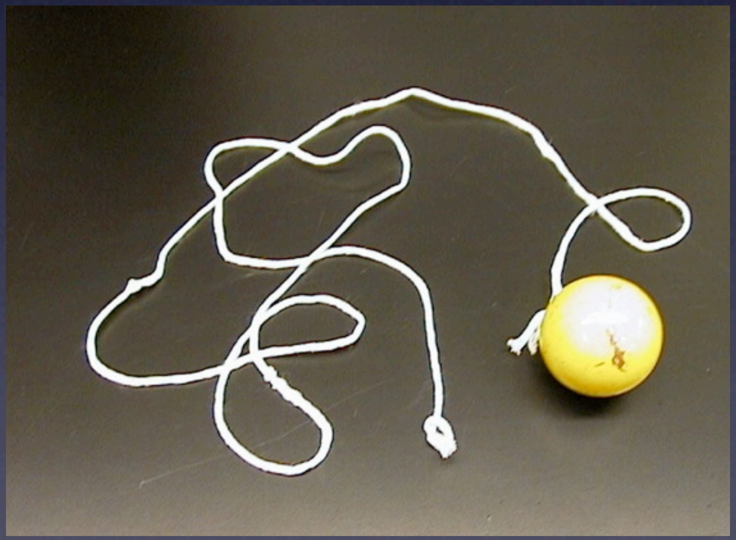
Example 1: Shape of the earth

True or false? Our everyday experience clearly points to the fact that the earth is round.

Agree or disagree? Students' daily experience has no bearing on teaching that the world is round.

Example 11: Motion of objects

Research suggests that when asked to draw the trajectories of objects released from (for example) continuous rotations or curved enclosures...



...Most individuals did not know that objects move in straight lines absent some external force.

Agree or disagree?   Student misconceptions play a large role in science learning.

Pedagogical Implications

Brains connect new information to old

Learning depends on 'points of reference' bridging new ideas with old ideas.

Brains are highly plastic

Our brains can ‘rewire’ themselves in response to trauma or disease or disability

Example: Dyslexia interventions

Multiple representations of concepts seems to be the key to developing deep understanding

Example: Three-ness

Conclusions

Certain patterns of thought are common among human beings.

Understanding the ways in which our brains work in common can give us insights into pedagogical challenges.

Sources and Further Reading

Book: Tracey Tokuhama-Espinosa, *Mind, Brain, and Education Science* (2011)

Book: John D. Bransford, Ann L. Brown & Rodney R. Cocking, *How People Learn* (2000)

Book: Richard A. Duschl, Heidi A. Schweingruber & Andrew W. Shouse, *Taking Science to School* (2007)

Article: Stanislas Dehaene, Serge Bossini & Pascal Giraux, *The mental representation of parity and number magnitude* (1993)

Article: Daniel Ansair & Annette Karmiloff-Smith, *Atypical trajectories of number development* (2002)

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