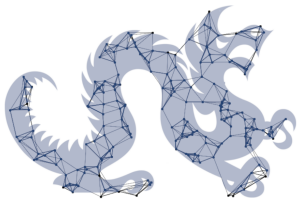
Modeling Instruction, student engagement, and neurobiological impacts

Eric Brewe
Drexel University
4 March 2019
Colloquia at Rutgers University



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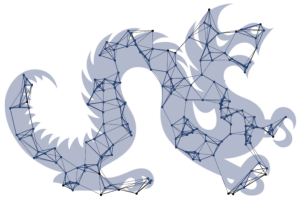
QR Code

https://ericbrewe.com/slides/RutgersColloquium.pdf



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Special Thanks to FIU PER Group

Modeling Instruction – Theory

- Science is a modeling endeavor (Hestenes, 1987)

Bizarre Particles Keep Flying out of Antarctica's Ice, and They Might Shatter Modern Physics

Cosmic rays emanating from the south polar ice cap could lead to new physics

How Bad Is Bacon for You, Really?

By Leslie Nemo, Live Science Contributor | October 7, 2018 11:54am ET

Credit: Shutterstock

We have 12 years to limit climate change catastrophe, warns UN

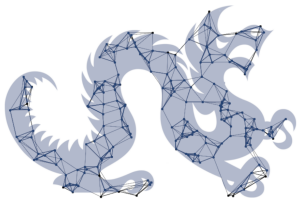
Urgent changes needed to cut risk of extreme heat, drought, floods and poverty, says IPCC

Overwhelmed by climate change? Here's what you can do

▲ A firefighter battles a fire in California. The world is currently 1C warmer than preindustrial levels. Photograph: Ringo HW Chiu/AP

Modeling Instruction – Theory

- Science is a modeling endeavor
  - Constructing new models
  - Testing/Validating models
  - Deploying models to new situations
  - Revising models



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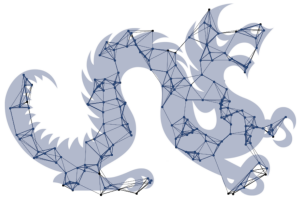
Hestenes, 1987; Halloun, 2004; Brewe, 2008; Giere, 1989, Etkina 2006

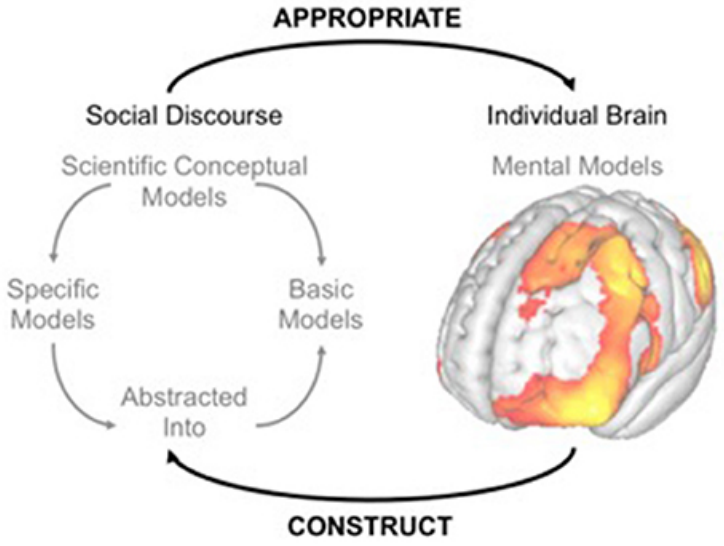
Modeling Instruction – Theory

- Science is a modeling endeavor…what is a model?
  - An abstract representation of structure
    - Hestenes, Halloun
  - Models mediate thought
    - Johnson-Laird, Morgan and Morrison
  - Constructs that stand in for phenomena
    - Giere, Nercissian
  - Allow students to address new phenonmena
    - Odenbaugh, Gouvea & Passmore, Svoboda & Passmore

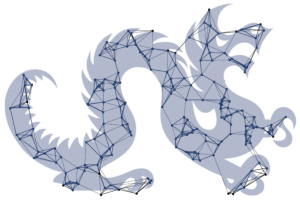


Modeling Instruction – Theory

- Science is a modeling endeavor…what is a model?



"Conceptual models are purposeful coordinated sets of representations (e.g., graphs, equations, diagrams, or written descriptions) of a particular class of phenomena that exist in the shared social domain of discourse"
(Brewe & Bartley et al., 2018)



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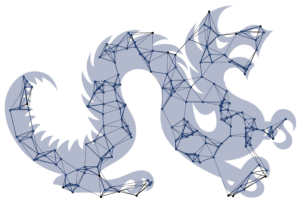
Modeling Instruction – Theory

- Purposeful coordinated sets of representations (e.g., graphs, equations, diagrams, and/or written descriptions) of a particular class of phenomena that exist in the shared domain of discourse.

  - Composition – Representations
  - Purpose – Mediate thought
  - Domain – Social Discourse



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Modeling Instruction – Theory

http://univ-modelinginstruction.com/

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Modeling Instruction – Exposition

Typical Instructional Cycle

- Activity (Lab, Conceptual or Problem Solving) in small groups

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Modeling Instruction – Exposition

Typical Instructional Cycle

- Whiteboard in small groups

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Modeling Instruction – Exposition

Typical Instructional Cycle

- Large Group 'Board Meeting'

Modeling Instruction – Exposition

Typical Instructional Cycle

- Large Group 'Board Meeting'

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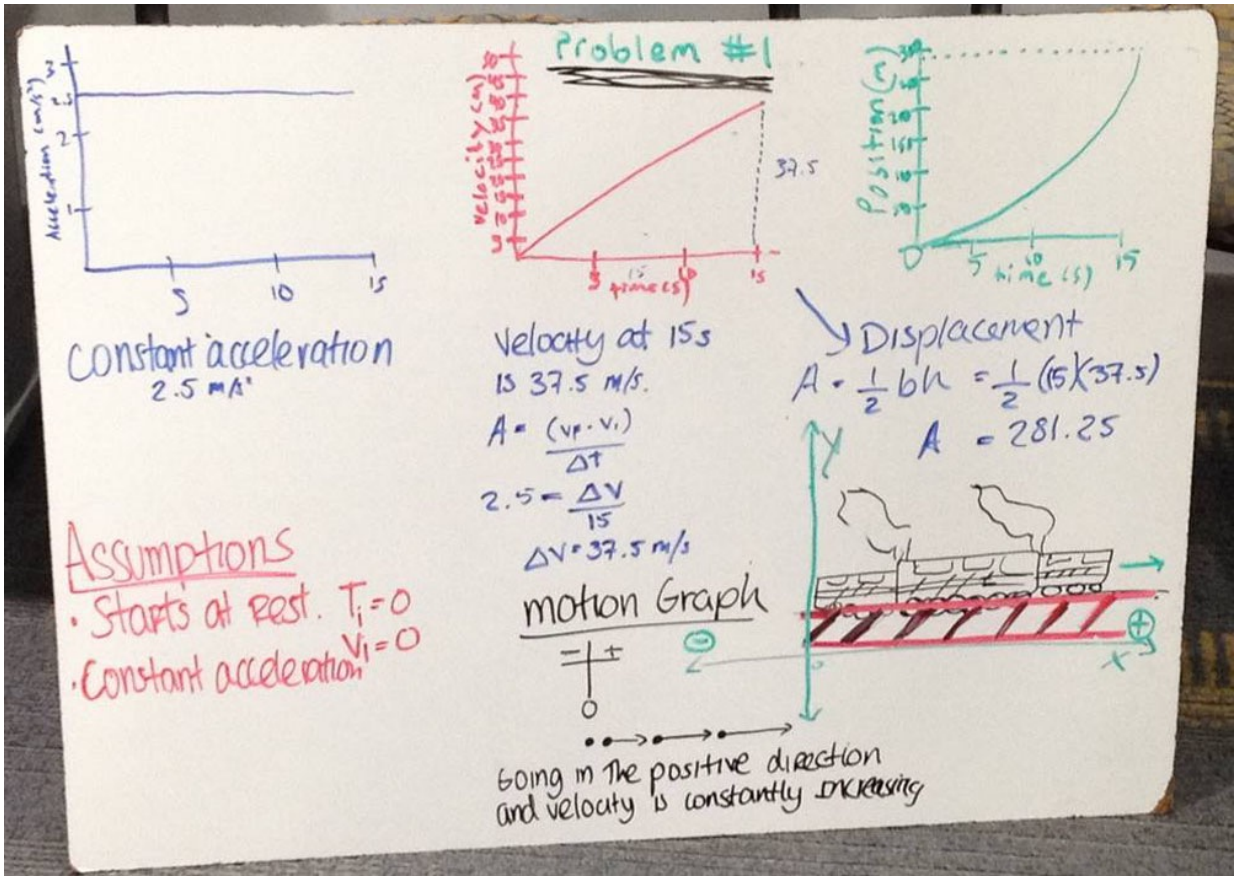
Modeling Instruction – Theory



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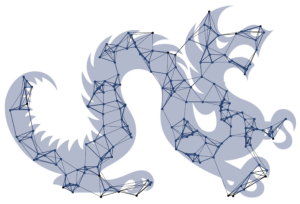
FMRI – Studies in MI classrooms

- We have evidence that students are learning
- What does that mean from a neurobiological perspective?
  - Can we look at physics reasoning in brains?
  - Can we identify differences after instruction?
  - Can we find evidence of students mental models?



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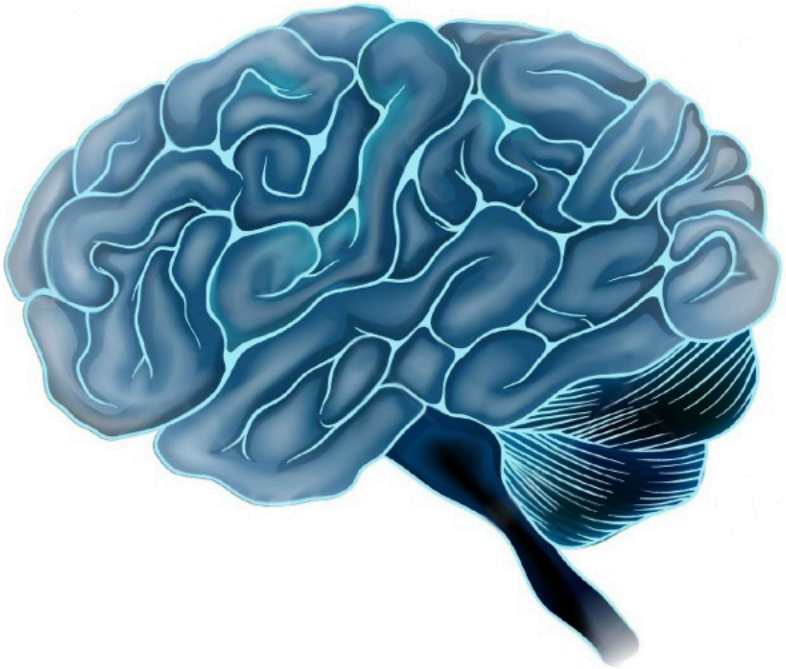
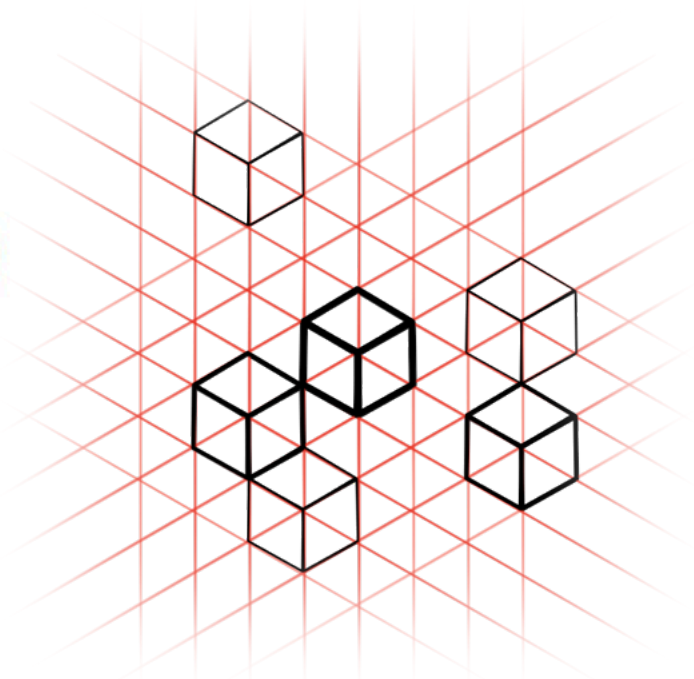
DID SOMEONE SAY BRAINS?

FMRI – Data Collection





Blood Oxygenation Level Dependent imaging

- Brain divided into ~1,000,000 voxels
- fMRI measures haemodynamic response to neural activity (% change in BOLD)
- **Task / Recall / Control / Rest**

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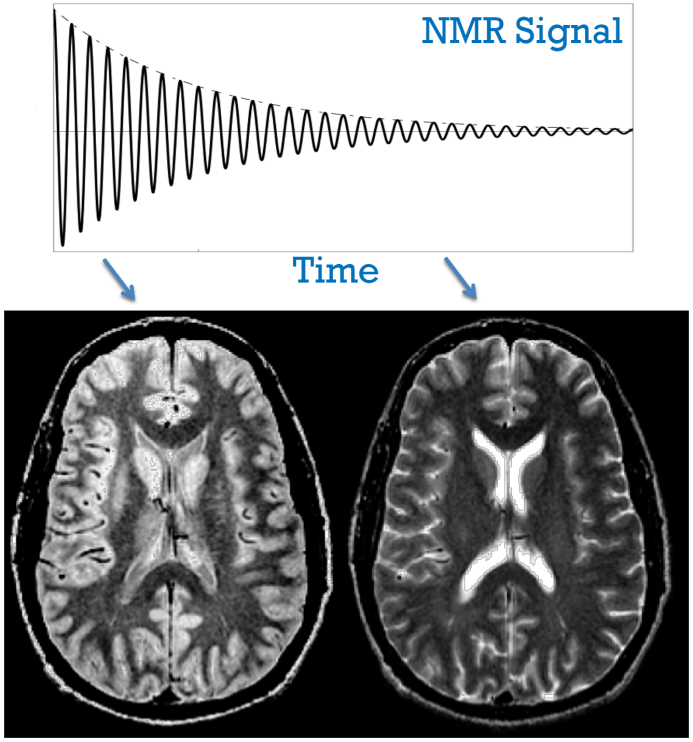
FMRI – Pre-processing

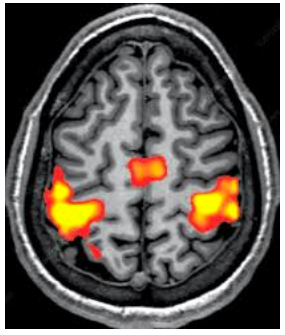
- Anatomical processing:
  - Skull stripping
  - Mapping to Brain Atlas
- Reducing noise:
  - Masking
  - Regressing out motion
  - Alignment to reference
  - Temporal adjustments



FMRI – Analysis

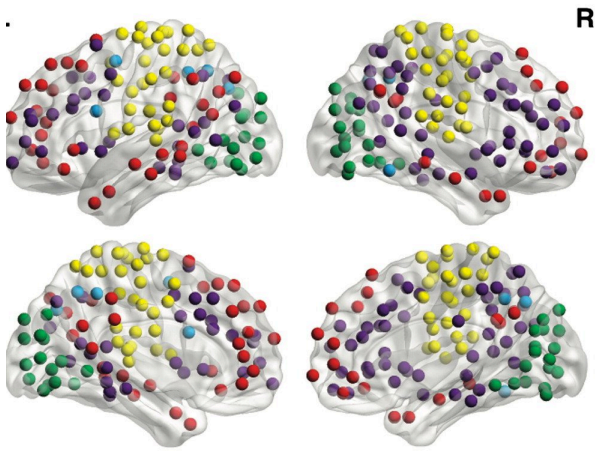
Statistical

- Identify areas of brain activity that correlate with task
- Subtractive
  - Task – Recall
  - Post – Pre
  - Data = Images



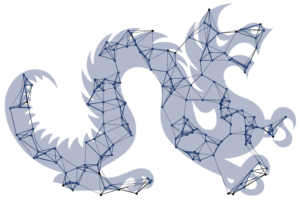
Functional Connectivity:

- Identify areas of co-activation.
- Graph theoretic



FMRI – Three Studies

1. Task validation / Study of Reasoning patterns
2. Study of MI Students
3. Comparison of MI / Lecture



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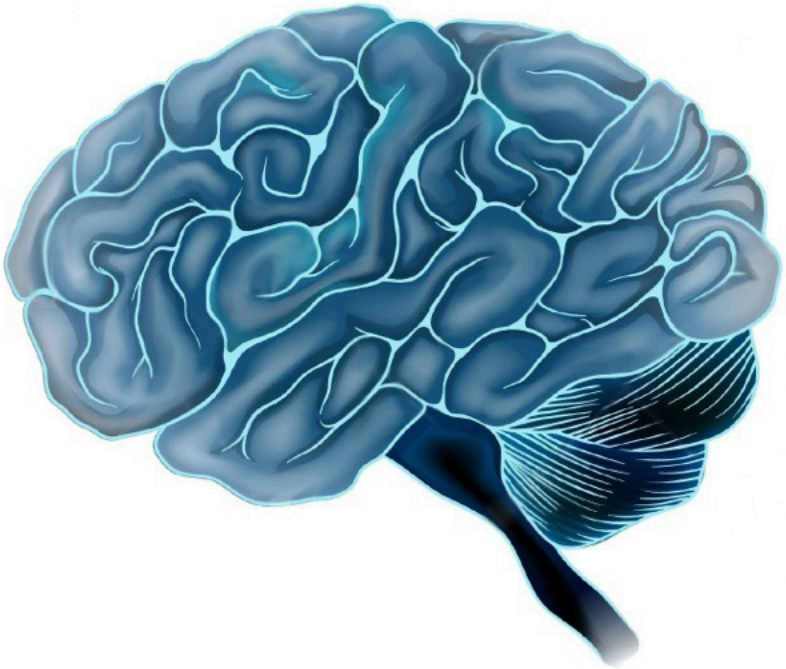
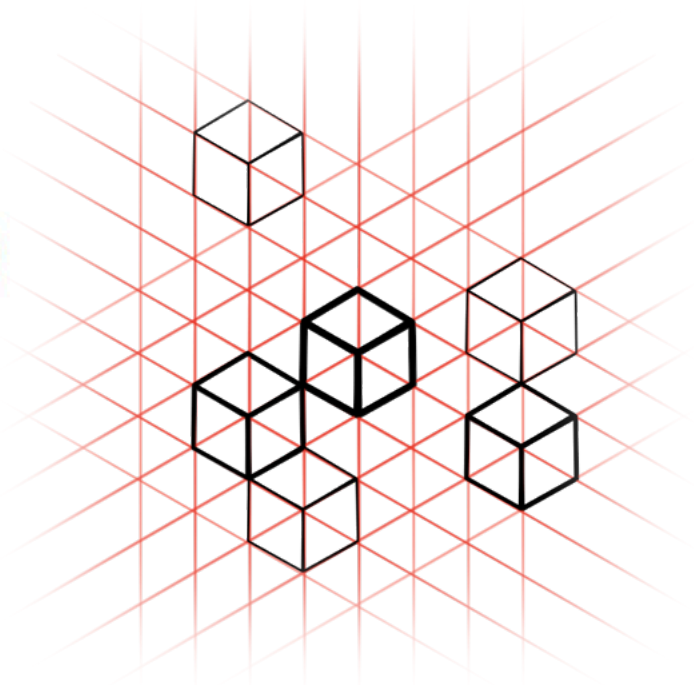
FMRI – Study Details





Participants

107 students (Pre and Post Instruction Scans)

48 female, 59 male

55 MI participants (22 female, 33 male)

52 Lec participants (26 female, 26 male)

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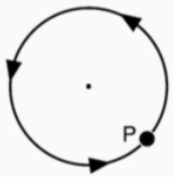
a) Example FCI Question

A ball is attached to a string and swung in a horizontal circular path. At point P the string suddenly breaks near the ball.

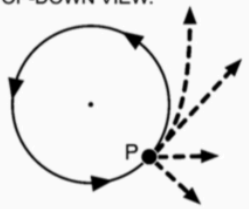
TOP-DOWN VIEW:



A ball is attached to a string and swung in a horizontal circular path. At point P the string suddenly breaks near the ball.

Which path would the ball take after the string breaks?

TOP-DOWN VIEW:



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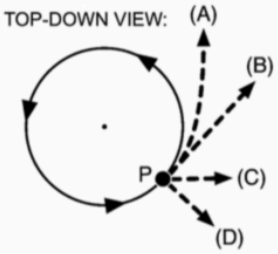


(A) The ball would move along path A.
(B) The ball would move along path B.
(C) The ball would move along path C.
(D) The ball would move along path D.

b) Example Baseline Question

A child is playing with a basket of toy blocks of varying size. The blocks are labeled the with letters "R", "G", and "B".

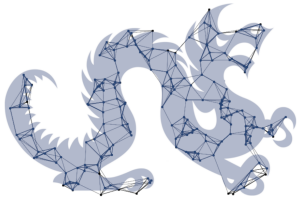
A child is playing with a basket of toy blocks of varying size. The blocks are labeled the with letters "R", "G", and "B".

Which block is the largest and which is the smallest?

A child is playing with a basket of toy blocks of varying size. The blocks are labeled the with letters "R", "G", and "B".

Which block is the largest and which is the smallest?

(A) The smallest block is labeled "R" and the largest is labeled "G".
(B) The smallest block is labeled "B" and the largest is labeled "R".
(C) The smallest block is labeled "G" and the largest is labeled "B".
(D) The smallest block is labeled "R" and the largest is labeled "B".



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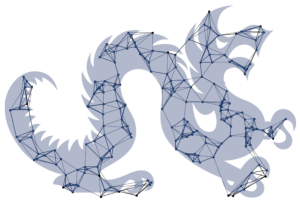
Study #1: Task validation and Physics Reasoning

Bartley, Riedel, Salo, Boeving, Bottenhorn, Odean, Nazareth, R. Laird, Sutherland, Pruden, Brewe, A. Laird. (2019). Brain activity links performance in science reasoning with conceptual approach. *NPJ science of learning*, *4*(1), 1-8.



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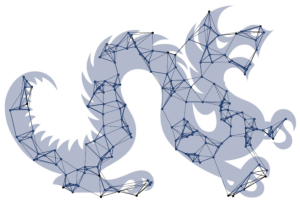
Study #1 – Task validation & Physics Reasoning

- Use Post data and Reasoning - Control
  - What areas are more active during reasoning vs recall?
- Competing theories for wrong answers:
  - Result of compiled thinking
  - Physical intuitions
  - Resources deployed to analyze new situations
- Do we see differences based on right/wrong?



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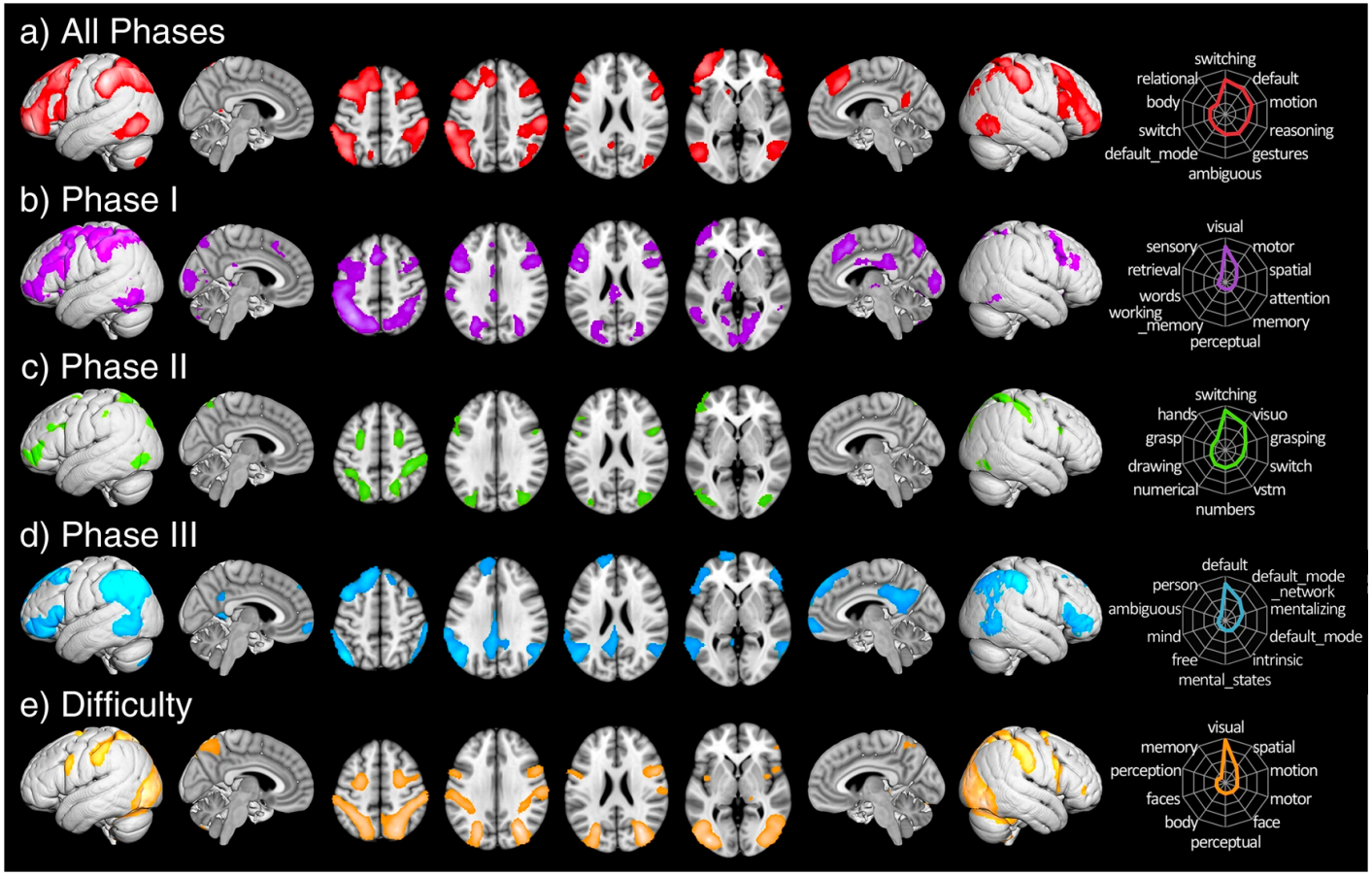
FMRI – Studies in MI classrooms

- No differences by correctness
- Different areas in different phases of the question.



Task Effects (FCI > Control)

Bartley et al. (2018)

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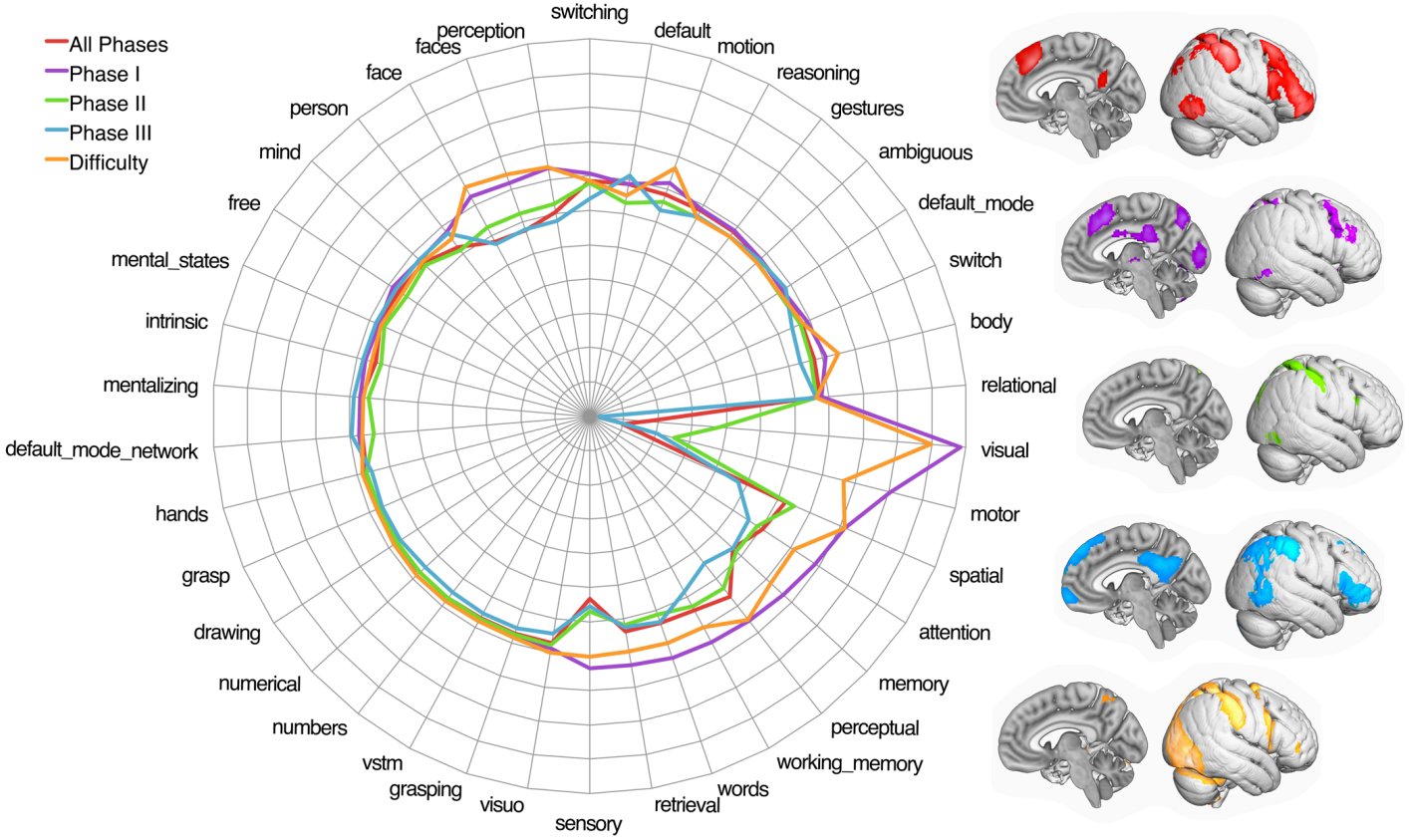
FMRI – Functional Decoding

Greatest Diff.

- Default Mode
- Visuospacial Pececptual
- Memory
- Attention



Task Effects (FCI > Control)

Bartley et al. (2018)

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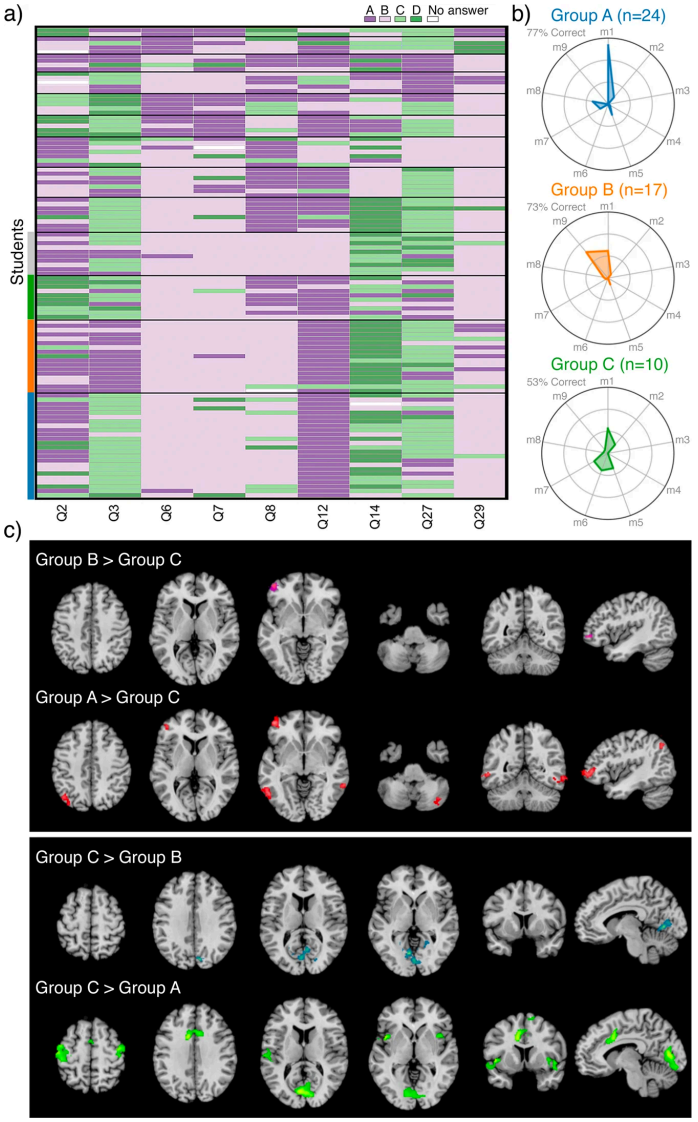
FMRI – Differences by conceptual model

Group students Module Analysis
Do we see differences by type of answer given?
One way ANOVA shows differences by group, $p<<0.001$

- Group A, 77% correct responses
- Group B, 73% correct, but greater prevalence of impetus force
- Group C, 53% correct, impetus force, greater force yields greater result



Grouping Effects

Bartley et al. (2018)

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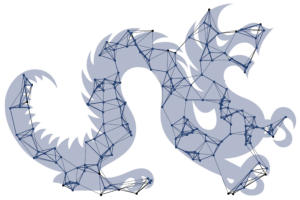
Study #2: Study of MI Students

Brewe, Bartley, Riedel, Sawtelle, Salo, Boeving, Bravo, Odean, Nazareth, Bottenhorn, R Laird, Sutherland, Pruden, A. Laird (2018). Toward a neurobiological basis for understanding learning in university modeling instruction physics courses. *Frontiers in ICT*, *5*, 10.



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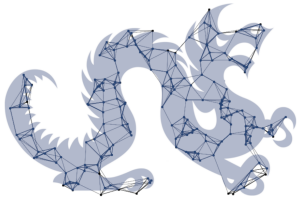
Study #2 – Study MI Students

- Use Pre and Post data, Reasoning - Control
  - Instruction effect; What areas are more active in MI students post vs pre?
  - Reasoning effect: What areas are more active in MI students in reasoning vs. control?
- Do we see differences based on right/wrong?



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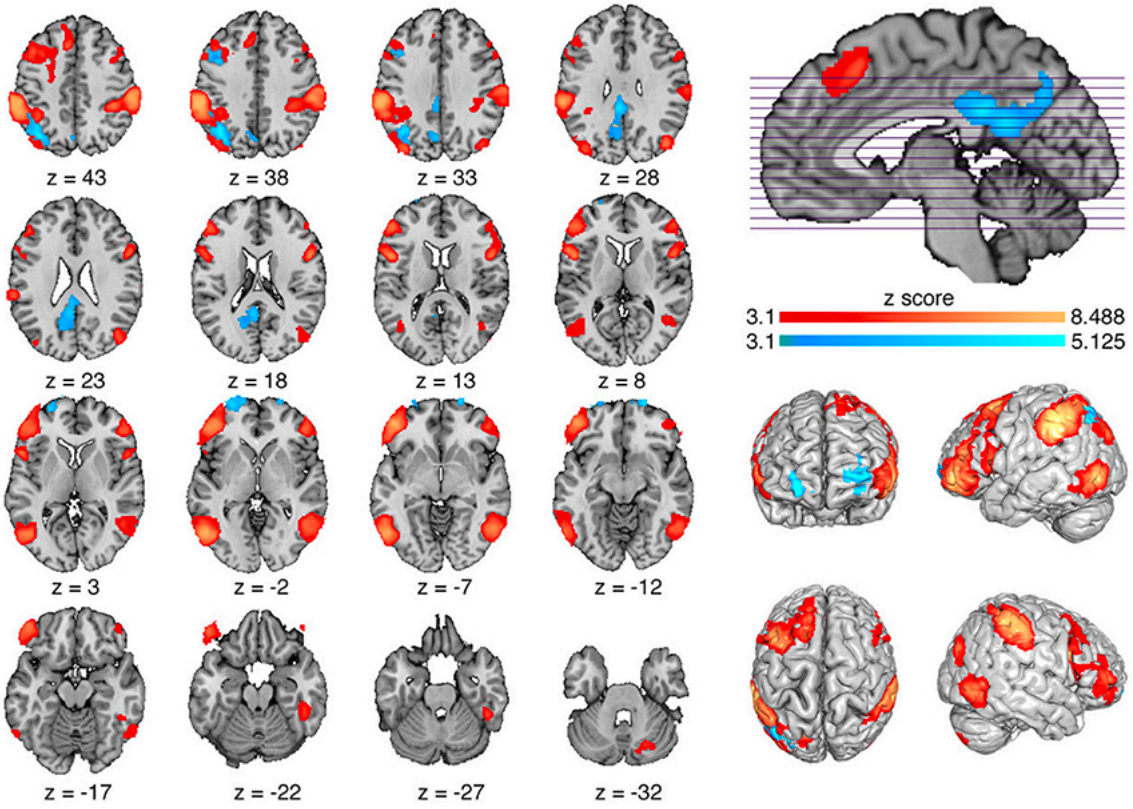
FMRI – Studies in MI classrooms

Task Effect: lateral prefrontal and parietal activations.

- Attention,
- Working memory,
- Spatial reasoning,
- Mathematical cognition



Red = Task Effects (FCI > Control)

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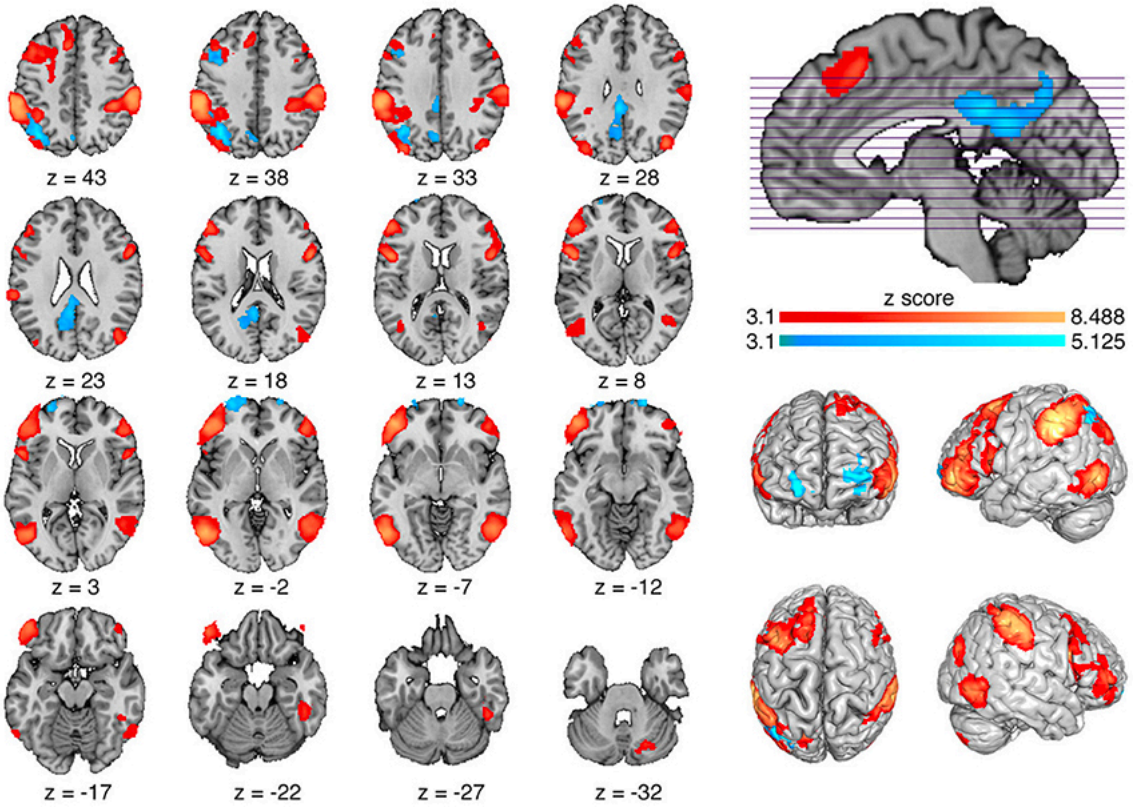
Brewe, Bartley et al. (2018)

FMRI – Studies in MI classrooms

Instruction Effect: posterior cingulate, frontal poles, dlPFC, angular gyrus.

- Narrative comprehension,
- Semantic processing,
- Generating & manipulating mental images



Blue = Instruction Effects (Post > Pre)

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Brewe, Bartley et al. (2018)

FMRI – Studies in MI classrooms

IFLSCIENCE!

Learning Physics Changes How Your Brain Works

8.0K SHARES

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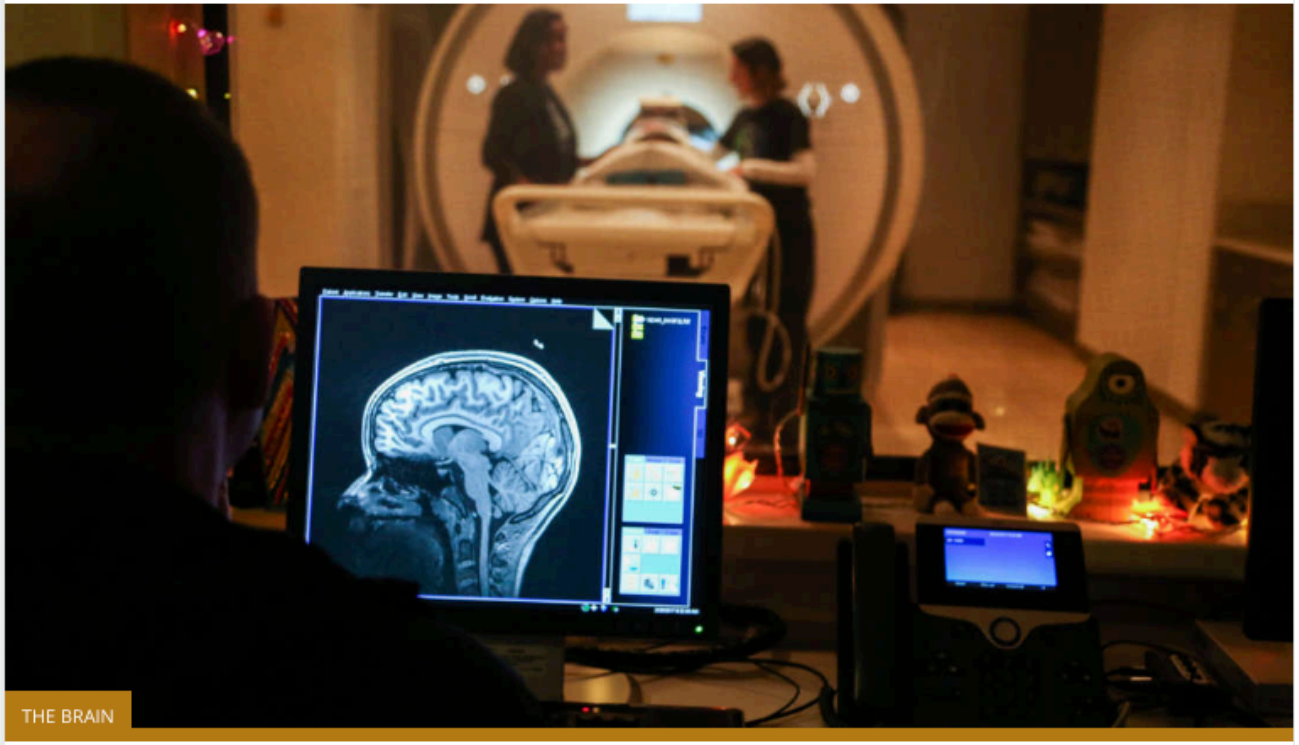

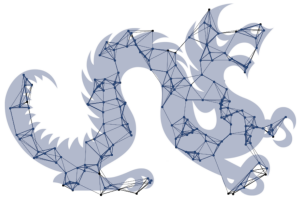

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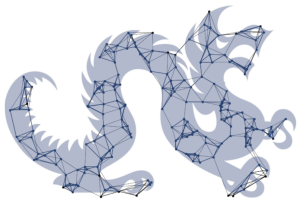
Study #3: Comparing MI and Lec

Bartley, J.E., Riedel, M., Salo, T., Boeving, E.R., Bottenhorn, K.L., Boeving, E., Laird, R.W., Sutherland, M.T., Pruden, S.M., Brewe, E., and Laird, A.R. (2019 - Under Review 12 December 2019). Sex and pedagogy influences in physics learning-related reorganization of brain activation.



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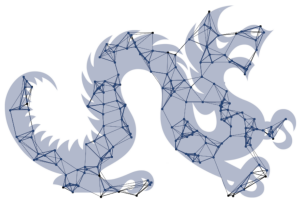
Study #3 – Study MI and Lecture

- The spicy burrito.
  - Post - Pre
  - Female – Male
  - MI – Lec
  - Interaction effects



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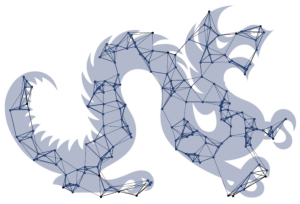
Study #3 – Study MI and Lecture

- Behavioral Differences (not in scanner)
  - Post v. Pre. Post > Pre
  - Female v. Male. Male > Female
  - MI v. Lec No differences



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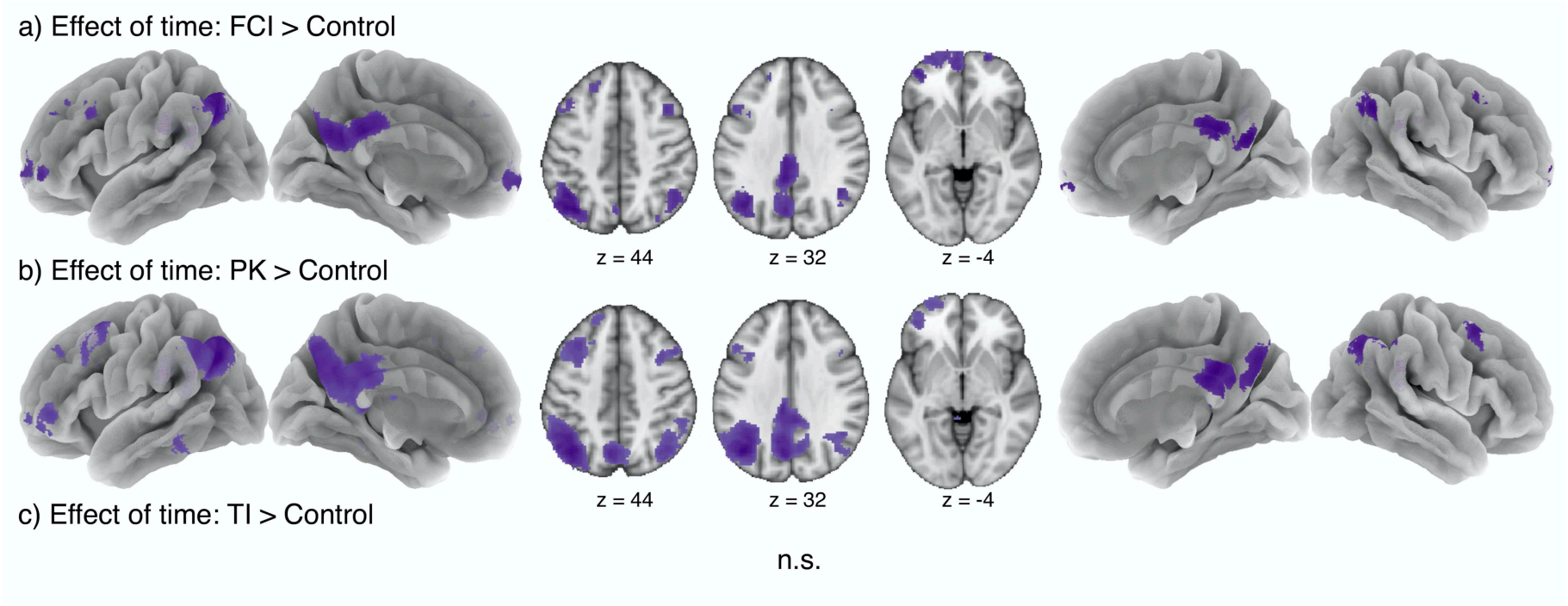
Study #3 – Study MI and Lecture

- Main Effects - time



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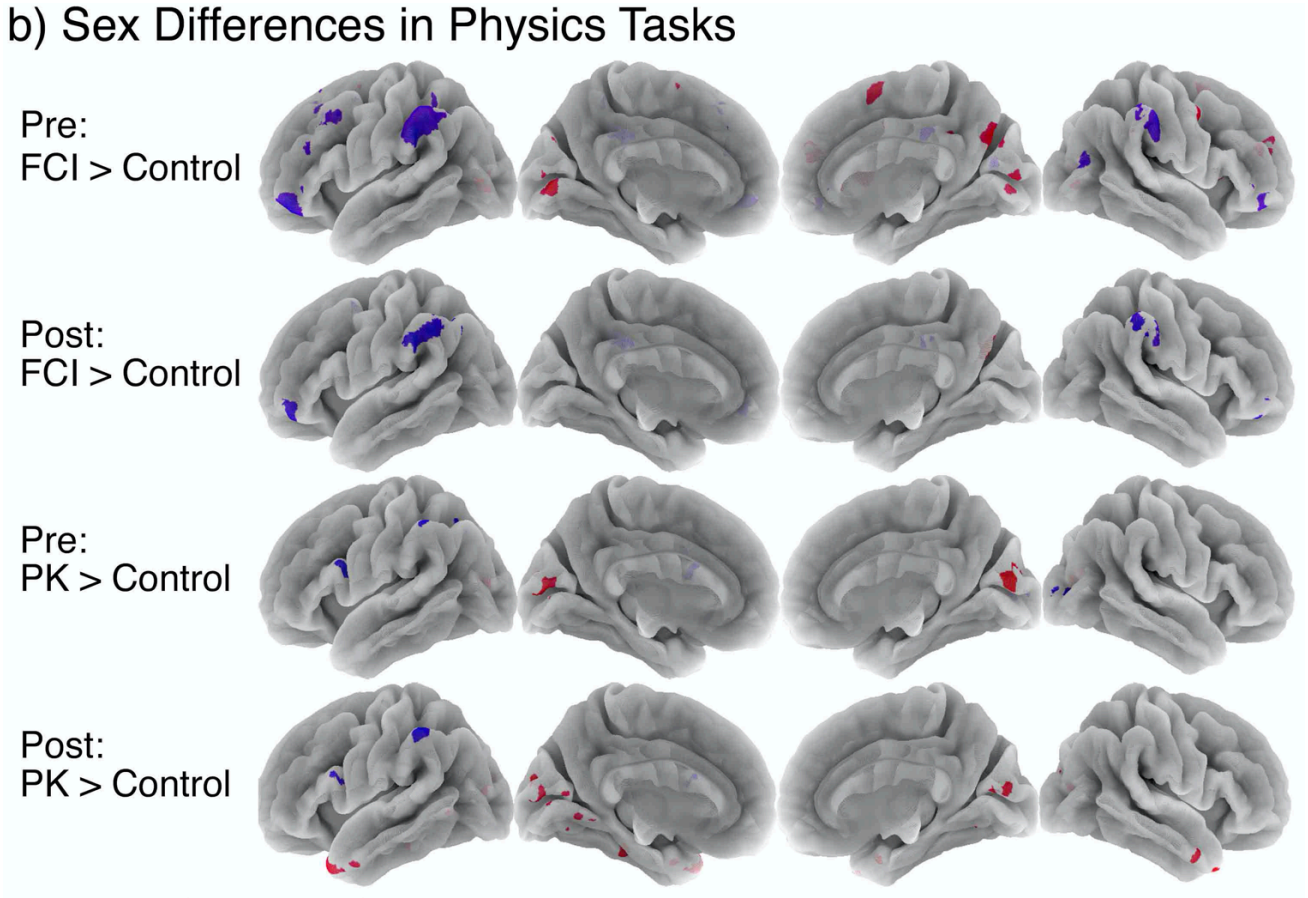
Study #3 – Study MI and Lecture

- Main Effects - sex



Red = Male > Female; Blue = Female > Male

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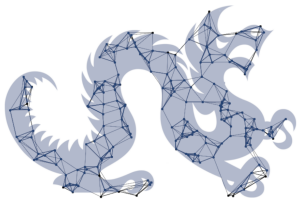
Study #3 – Study MI and Lecture

- Main Effects – class type



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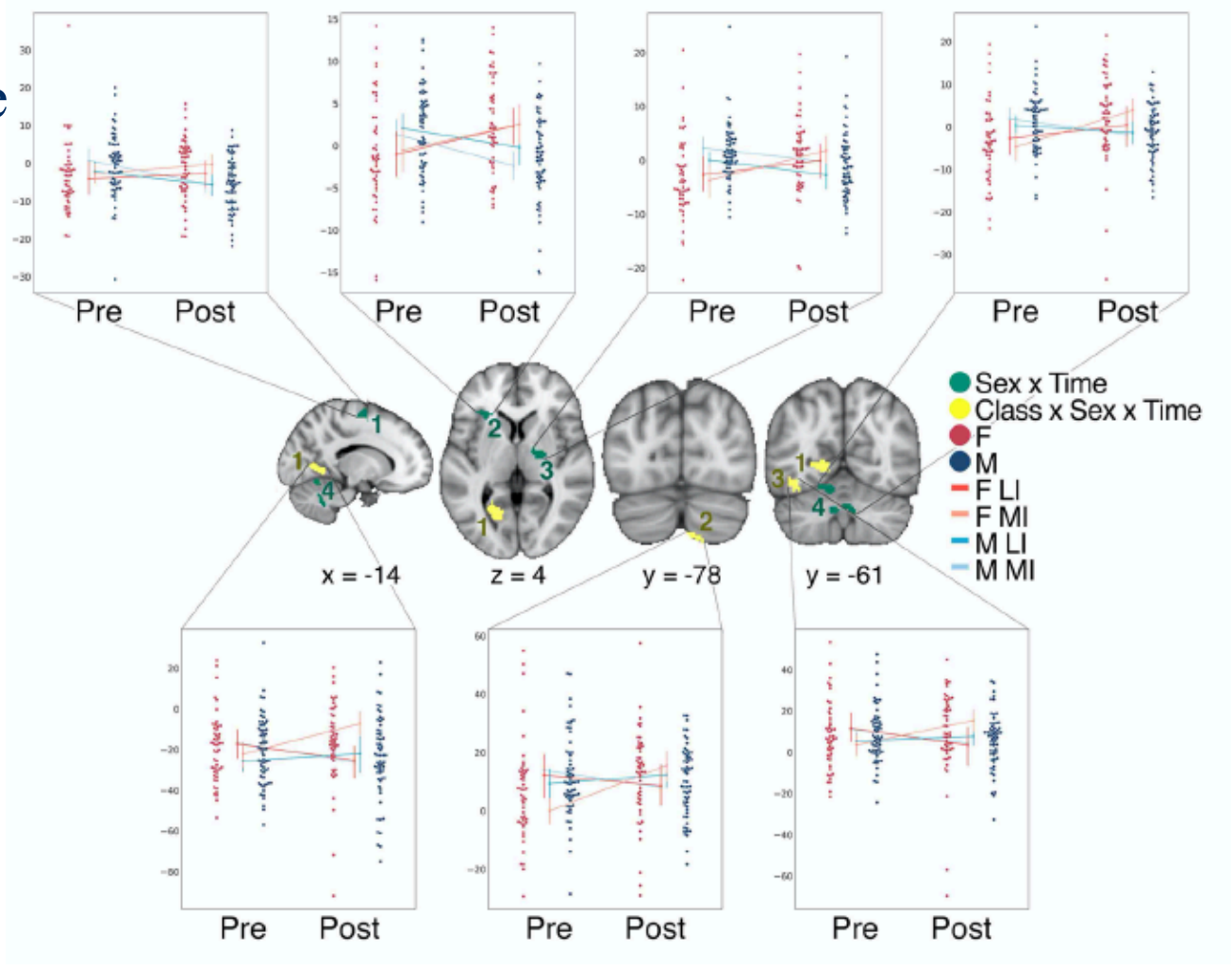
Study #3 – Study MI and Lecture

- Interactions: Class x sex x time

MI female, LI male show increases, while MI male and LI female exhibit decreases.

- Cerebellum
- Fusiform gyri
- Lingual gyri
- **Visualization areas**



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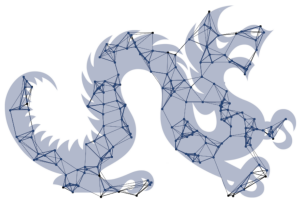
Summary- Accomplishments

- Began with a theory of physics learning
  - We've developed paradigm that has distinguished physics reasoning from physics recall
  - We have identified characteristics of neurobiological instructional differences in MI students
  - We have an initial understanding of differences between MI and Lecture students



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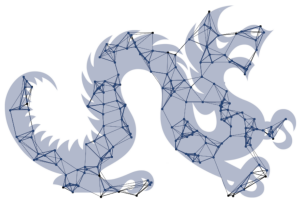
Summary- Results

- Reasoning ≠ Correctness
- MI Students in post-pre ⇒ activation patterns used in narrative, & generating mental images.
- Very minimal differences by sex
- No differences by class type
- Interaction effect sex x class type x time
  - Differences in areas that are associated with visualization.



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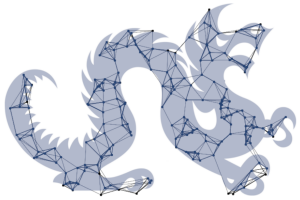
Future

- Analysis of STEM anxiety
- Greater emphasis on network analytic approach
  - Small worldness
- Further exploration of class type analyses
- Correlation with behavioral measures



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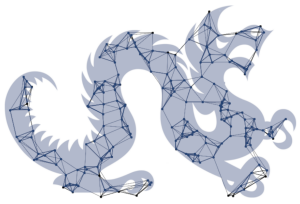
THANK YOU!



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