Creating a Science of Spatial Learning

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Why Spatial?

• Spatial skills and spatial learning are important
  – in human functioning in general
  – in the STEM disciplines in specific
• Spatial skills and spatial learning can be improved
  – thus increasing the STEM workforce and the population’s ability to engage in STEM discourse
• There are sex-linked and SES-linked differences in spatial skills and spatial learning
  – addressing these differences is important for social equity
Spatial thinking is pervasive in scientific discoveries and STEM education.
Predicting Occupations from High School Spatial Ability
Wai, Lubinski & Benbow (2009)

![Bar graph showing standardized score for different occupations]

- Education
- Law
- Social Science
- Humanities
- Dentistry
- Business
- Medicine
- Performing Arts
- Biological Science
- Visual Arts
- Physical Science
- Math/Computer Science
- Engineering

Standardized Score
Similar Findings in Early Childhood
Gunderson, Ramirez, Beilock & Levine
Developmental Psychology, 2012

Spatial skill (age 5) → β = .32, p < .05 → Approximate Symbolic Calculation (age 8)

Spatial skill (age 5) → β = .38, p = .01 → Number Line (age 6) → β = .50, p = .001 → Approximate Symbolic Calculation (age 8)

Number Line (age 6) → β = .13, n.s. → Approximate Symbolic Calculation (age 8)

Note: All models control for vocabulary at age 6.
Spatial Skills Can Be Improved

- Initial meta-analysis of training studies
- Two recent studies showed that improvement is *durable* and *transferable*
  - Terlecki, Newcombe & Little (2008)
  - Wright, Thompson, Ganis, Newcombe & Kosslyn (2008)
New Meta-Analysis Supports Malleability


- Solid training effects, as well as durability and transfer
Possible Effects

![Possible Effects Diagram](image-url)
Experimental Findings in Children

• Cheng & Mix (under review)
  Training spatial transformation
  → better scores on missing addend problems

• Grissmer et al. (under review)
  Copying designs in after-school arts program
  → better math scores
Experimental Findings in Adults

• Small & Morton (1983)
  Spatial training $\rightarrow$ better grades in chemistry

• Sanchez (2012)
  Spatial training $\rightarrow$ better essays in geoscience

• Miller & Halpern (2012)
  Spatial training $\rightarrow$ better grades in physics

• Sorby et al. (under review)
  Spatial training $\rightarrow$ better grades in calculus
Learning from External Symbol Systems

- Language
- Maps, Diagrams, Graphs, Sketches
Learning from Spatial Alignment and Analogy

• Analogy is widely used in spatial learning
  – in early childhood
  – in geoscience
Learning from Action-to-Abstraction

- Embodied cognition
  - But action sometimes hurts and sometimes helps
- Gesture
  - e.g., in discussions on geological field trips
- Sketching
  - e.g., in engineering design
We Need To Characterize and Assess Spatial Skills
Relation Between Classroom and Lab

- Conducting smaller-scale studies provides a sound basis for large-scale educational change—where the wheel goes around more slowly.
- Sometimes we disengage the belt, letting the small wheel spin and waiting for success to re-establish the connection to the large wheel.
Challenges for the Future

• Delineate mechanisms more finely
  – e.g., the role of the number line
• Examine what techniques work best in what contexts, how they work together, and how they work with non-spatial techniques