Why Spatial Reasoning Matters for Education Policy

Jonathan Wai and David H. Uttal
What is spatial reasoning?

• “[T]he ability to generate, retain, retrieve, and transform well-structured visual images.”

• Spatial reasoning can be measured through reliable and valid paper and pencil tests.
What is spatial reasoning?

• Reasoning, mental representation, and transformation of information about
  • Locations in space
  • *Relations among those locations*
What are examples of people high in spatial reasoning?

- Albert Einstein famously imagined chasing after a light beam. This *gedankenexperiment* led to his first published paper, at age 16, titled “The Investigation of the State of Aether in Magnetic Fields,” and eventually to the creation of the theory of relativity.
What are examples of people high in spatial reasoning?

- Engineers at Space-X. Here is the “Falcon Heavy.”
Why is spatial reasoning important?

• Navigation
• STEM learning and reasoning
Why is spatial reasoning important?

• Spatial reasoning predicts performance in STEM fields over and above verbal and mathematical reasoning. Early spatial talent has even been linked to later creativity.

• Spatial reasoning is also important for vocational, manufacturing, and visual arts areas.

• Creativity today is associated with acting, dancing, artistry, music, and writing. Society often overlook’s the creative value of STEM and spatial reasoning.
• “At the present time, there is a developing educational crisis, because of the unsatisfied demand for personnel trained and qualified in all fields in which spatial ability is of fundamental importance. The technical revolution has put a premium on spatial ability at all levels, whether required for tile-laying or for topology.” – I. M. Smith (1964)

• “Employers complain that electricians, pipe fitters, advanced manufacturing machinists, brick masons and radiology technicians are scarce. More than 600,000 jobs remain open in the manufacturing sector alone. These are jobs that provide a middle-class wage without a traditional four-year college degree.” – Newman and Winston (2016)
What’s missing in standardized tests?

- K-12 standardized tests
- College admissions tests
- Graduate admissions tests
- Job selection tests
What is missing in standardized tests? How does this affect education?

• Students who have spatial reasoning strengths but relative math and verbal reasoning weaknesses are disadvantaged throughout the education process:
  • K-12 education
  • Gifted education
  • College admissions
  • Graduate school admissions

• The lack of spatial measures likely has had a cumulative effect over decades. If you don’t identify talent early, you can’t develop it properly.
How malleable is spatial ability?

(Answer = .43 SD)

The Malleability of Spatial Skills: A Meta-Analysis of Training Studies

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Examples...

Engineering course using multi-media software and workbook:

- Improved Purdue Spatial Visualization Test performance (Sorby, 2008)

- Isometric pictorials from coded plans
- Multi-view drawings
- Paper folding/2-D to 3-D transformations
- Object rotations about one axis
- Object rotations about two or more axes
- Cutting planes and cross sections
- Surfaces and solids of revolution
- Combining solids
Examples...

• Effect of playing videogames (Tetris) on mental rotation (Terlecki, Newcombe, & Little, 2008).
Training lasts

• Post-tests taken immediately after training demonstrated approximately equivalent improvement to delayed post-tests.

• *No significant decline in* effect size measured immediately, within 1 week, within 1 month and over 1 month.
Training transfers

• No difference between No Transfer, Near and Medium Transfer effect sizes
So what?

**Standardized Spatial Ability**

**Probability**

**Standardized Spatial Ability**

-4  -2  0  2  4

-0.4 -0.3 -0.2 -0.1  0  0.1  0.2  0.3  0.4
So what?

Training in theory could double the number of people “spatially qualified” to be engineers.
Some success already demonstrated in improving STEM

The role of spatial training in improving spatial and calculus performance in engineering students

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Core recommendations for innovations and reforms in education policy

• Earlier spatial reasoning identification, training, and educational development.

• Teacher training and familiarity regarding spatial reasoning.

• Identifying a broader base of low-income talent by including spatial reasoning measures in selection tests.

• Spatial reasoning incorporated into personalized learning.

• Innovation in curriculum and program development for spatial talent.