Spatial STEM+C: Using Spatial Reasoning Training in the Elementary Grades to Improve Computational Thinking, Mathematical Performance, and Educational Justice Outcomes

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Educational Justice = the need to provide children with equal access to quality instruction, resources and other educational opportunities that remove roadblocks to full participation in the American dream of a college education and a career.
Foundational Publication

Impact of spatial abilities on career choices well established.

- Spatial reasoning is important in predicting who goes into STEM fields and who stays in STEM.
- No upper limit on the relation has been identified: The better one is at spatial skills, the better one is at getting into STEM.
How important is spatial thinking within a profession?

- An example from geology

![Legend](image)

**Figure 2.** Key (A) for bedrock mapping task and digitized maps for high (B) and low (C) geological knowledge (GK) participants.

Visual spatial ability predicted performance for novices, but not expert geologists.

Results ascribed to “circumvention of limits:” acquisition of domain-specific knowledge reduces or eliminates the effects of individual differences in spatial abilities.

**Figure 4** Results from Hambrick et al. (2011) spatial ability and expert geology performance. “GK” refers to geology knowledge.
Documented in many fields

- Chemistry

Chemists no better than novices at Shepard and Metzler figures, but really good with mental rotations of molecular models
Documented in many pursuits

Medicine

Dentistry

Chess
The Paradox

Even though spatial abilities are highly correlated with entry into a STEM field, they actually tend to become less important as a student progresses to mastery and ultimately expertise in a professional domain.
Hope for the spatially challenged.

- Spatial training is effective.*
- The effect of spatial training is durable.*
- Transfer of acquired spatial skills is possible.*

*Based on Uttal and Cohen’s 2012 meta-analysis of 25 years of research on spatial training.
Implications

In addition to nurturing spatial abilities within academic and professional contexts, we need to examine how underdeveloped spatial abilities can serve as barriers to entry in STEM and other disciplines.
Implications

Using such knowledge, we can then design ways to foster basic spatial abilities at all levels in education to help learners overcome barriers to entry presented by gatekeeping courses in STEM and other disciplines.
Inspirations


Spatial STEM+C Goal

- Iteratively develop and evaluate supplemental instructional activities that build early computational skills in elementary-aged children.
Logic Model
Study Sites
Approach

Implementing:
• Practical guided-inquiry activities
• Age-appropriate learning assessments
Supplies

- Design Blocks
- Keva Planks
- Legos Early Simple Machines Kits
- Legos Story Starter Kits
- Online Mapping Software
- Pattern Blocks
- Pentominoes
- Paper Maps
- Tangrams
- Whiteboards
Design Teams

• Two teachers/grade level (“Involved Teachers”)
• Biweekly meetings
• Highly collaborative
• Adaptive
• Personalized
Classroom Example 1
Classroom Example 2
Assessments: K-2

- Ekstrom Cube Comparison
- Front, Back, Left, Right-Opposite Perspective
- Left-Right
- Let’s Go Learn ADAM Mathematics
- Perspective Taking: Abstract, Concrete, and Contours
- Square Completion
Assessments: 3-5

- Ekstrom Cube Comparison
- Front, Back, Left, Right-Opposite Perspective
- Measure of the Ability to Form Spatial Mental Imagery (MASMI)
- Pearson adaptive mathematics assessment
- Square Completion
Comparison-Group Design

Each Grade Level

- Experimental
- Experimental
- Control
- Control

Involved Teachers

Spatial Thinking Interventions

Non-Involved Teachers

“Conventional” Curriculum

Total N ≈ 600

Full Academic Year
Pilot Test Results

- No preliminary quantitative results from pilot test
- Adjustments to spatial thinking assessments
- New mathematics assessments implemented
- Teacher anecdotes
<table>
<thead>
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<th>Year 2 Timeline</th>
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<td><strong>Pre-Test Assessments</strong></td>
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- Pre-Test Assessments
- Classroom Implementation
- Develop and Pilot Test Computational Thinking Assessment
- Post-Test Assessments and Teacher Focus Groups
- Data Analysis and eBook Production
- Final Report and Dissemination of Results
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