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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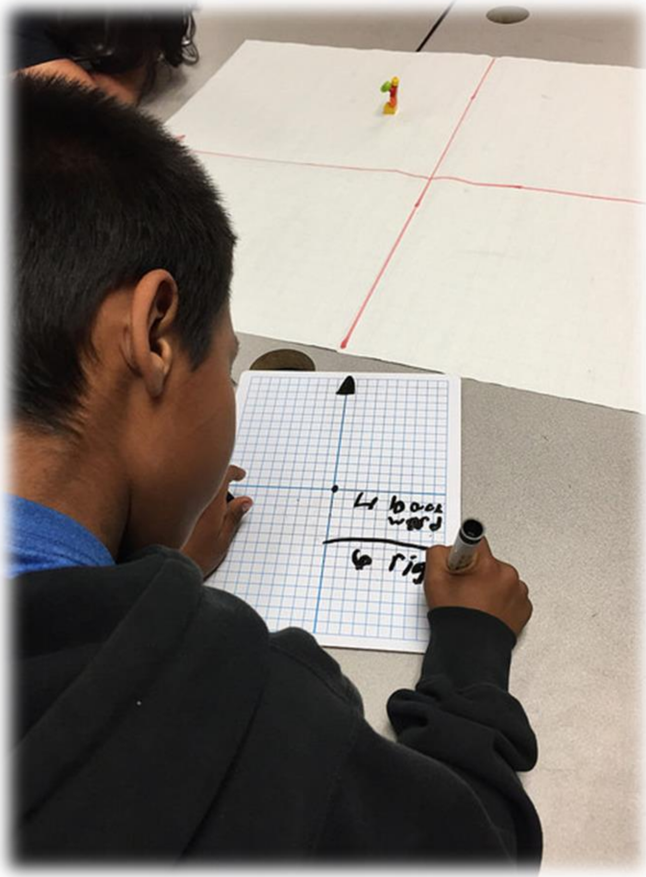
Foundation: Spatial Reasoning as an Educational Justice Concern

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

- Uttal, D. H., and C. A. Cohen. 2012. "Spatial Thinking and STEM Education: When, Why, and How?" In *The Psychology of Learning and Motivation, edited by B. H. Ross, 147-181. Elsevier.*

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.

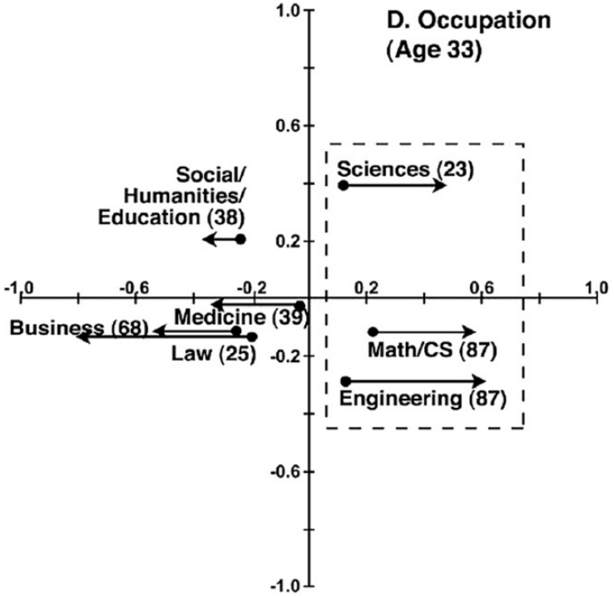


Figure 3 Results from Wai, Lubinski, and Benbow (2009). The X axis represents Math SAT, and the Y axis represents Verbal SAT, expressed in standard deviation units. The arrows are a third, or Z, dimension. The length of the arrow represents the unique contribution of the spatial ability test to predicting eventual career. (Reprinted with permission of the American Psychological Association.)

How important is spatial thinking within a profession?

- An example from geology

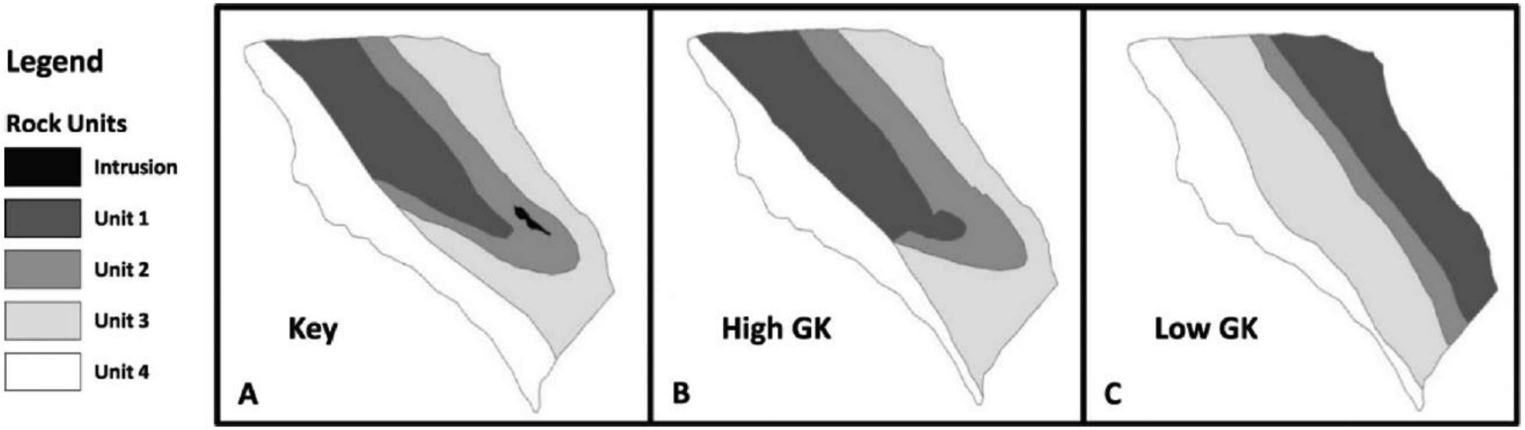


Figure 2. Key (A) for bedrock mapping task and digitized maps for high (B) and low (C) geological knowledge (GK) participants.

Hambrick, David Z., Julie C. Libarkin, Heather L. Petcovic, Kathleen M. Baker, Joe Elkins, Caitlin N. Callahan, Sheldon P. Turner, Tara A. Rench, and Nicole D. LaDue. 2012. "A test of the circumvention-of-limits hypothesis in scientific problem solving: The case of geological bedrock mapping." Journal of Experimental Psychology: General 141 (3):397-403. doi: http://dx.doi.org/10.1037/a0025927.

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.

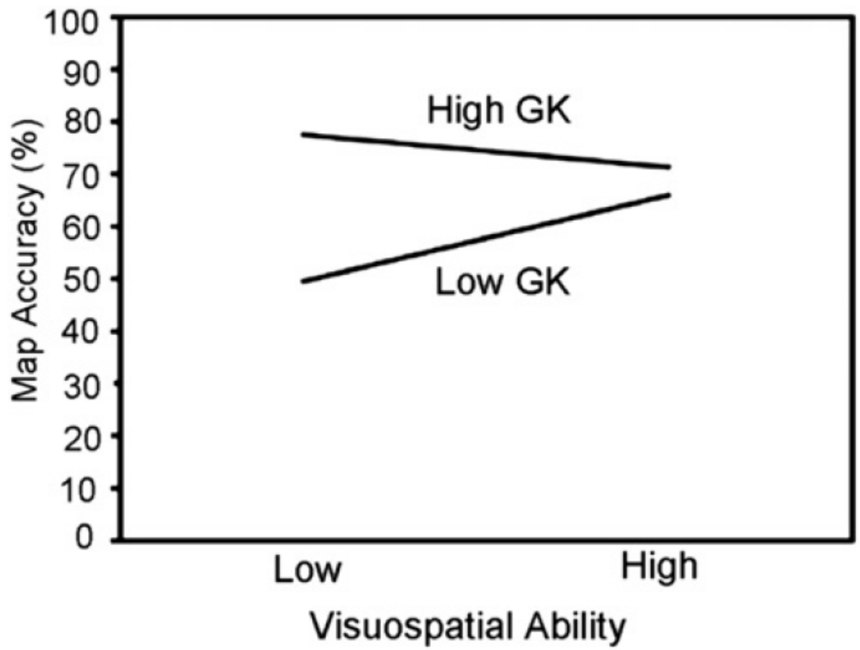
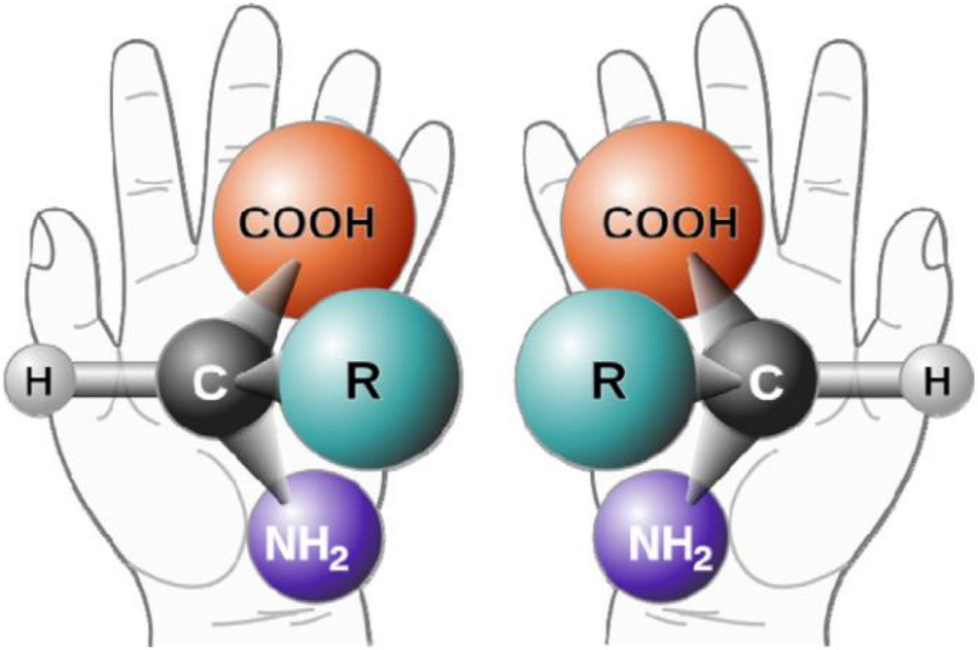


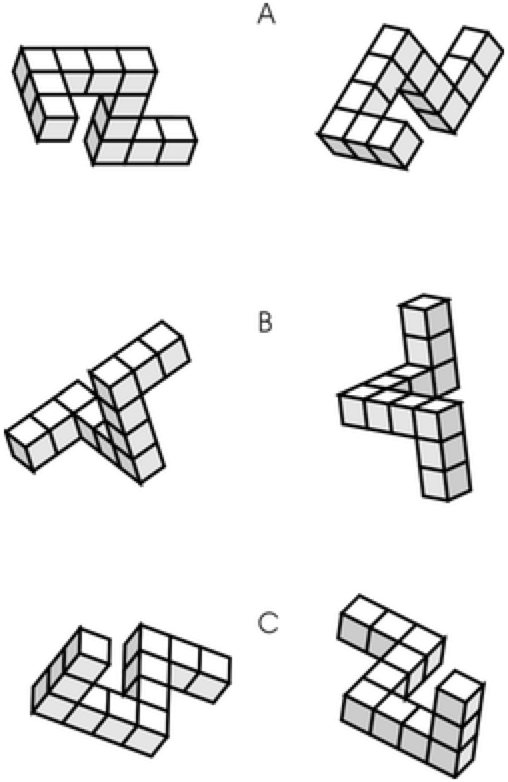
Figure 4 Results from Hambrick et al. (2011) spatial ability and expert geology performance. “GK” refers to geology knowledge.

Documented in many fields

- Chemistry



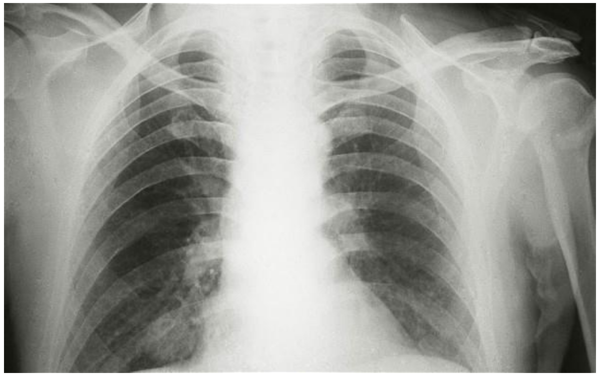
Vs.



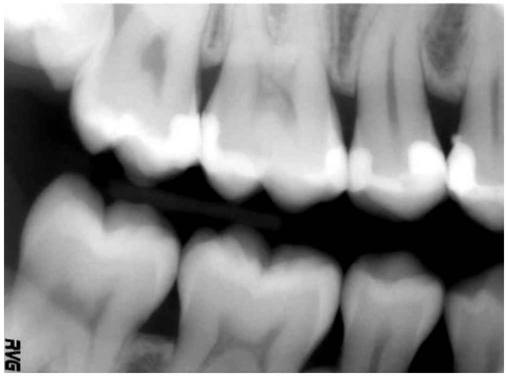
Chemists no better than novices at Shepard and Metzler figures, but really good with mental rotations of molecular models

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.

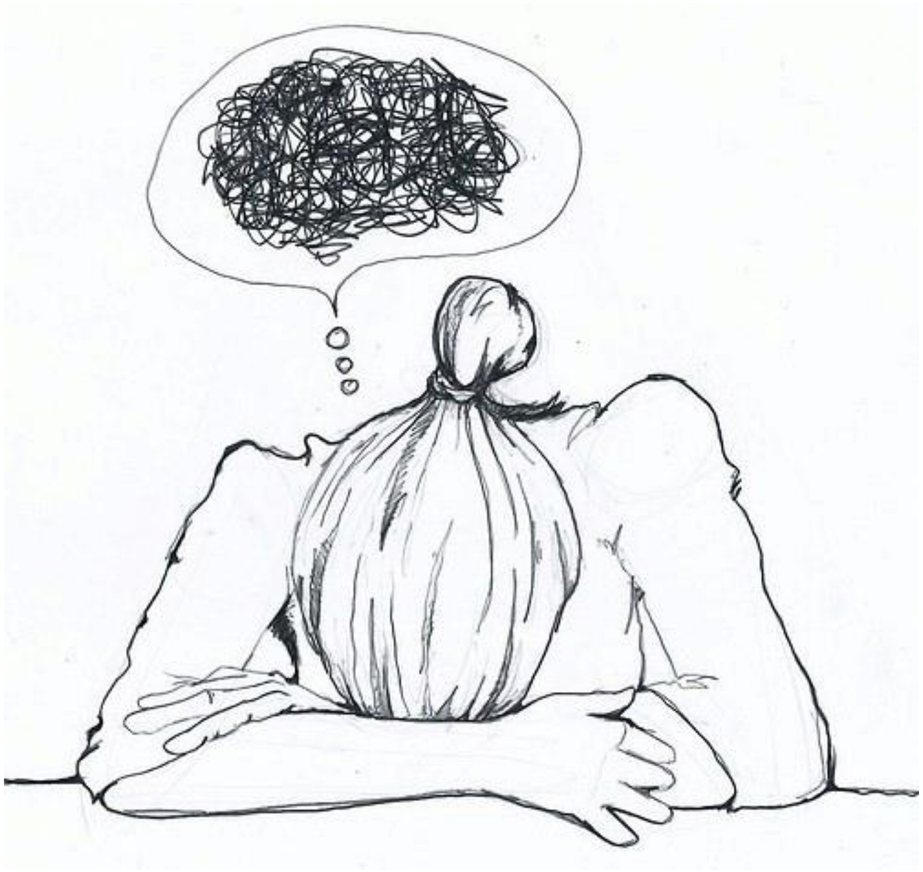
Hope for the spatially challenged.

- 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.

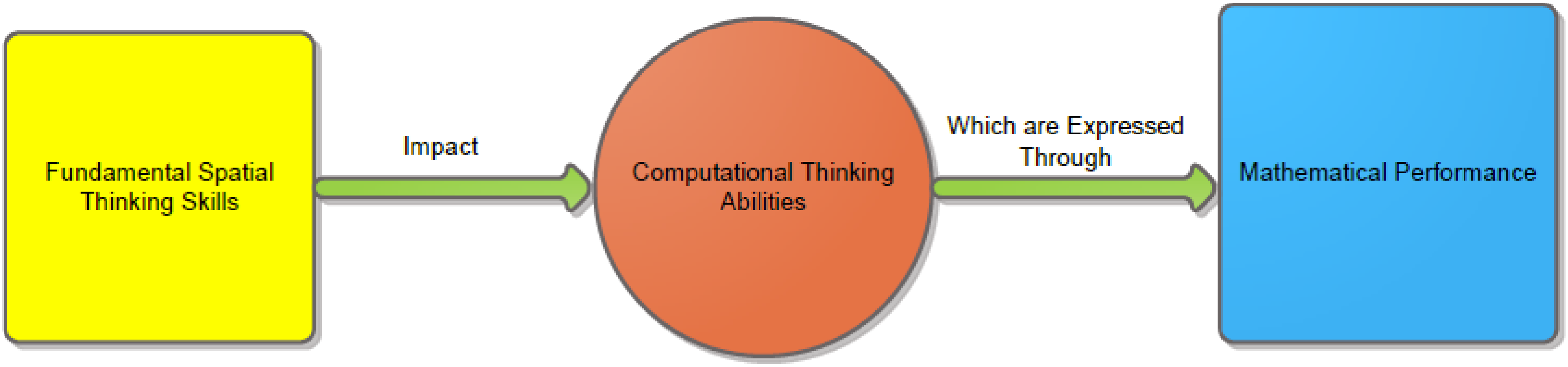
Inspirations

- Sorby, S. (1996). A course for the development of 3-D spatial visualization skills. Engineering Design Graphics Journal, 60(1), 13-20.
- Sorby, Sheryl A., and Beverly J. Baartmans. 2000. "The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students." Journal of Engineering Education 89 (3):301-307. doi: 10.1002/j.2168-9830.2000.tb00529.x.
- Sorby, S. (2009). Developing spatial cognitive skills among middle school students. Cognitive Processing, 10(Supplement 2), 312-315.
- Sorby, S. (2009). Educational Research in Developing 3-D Spatial Skills for Engineering Students. Internaitonal Journal of Science Education, 31(3), 459-480.

Spatial STEM+C Goal

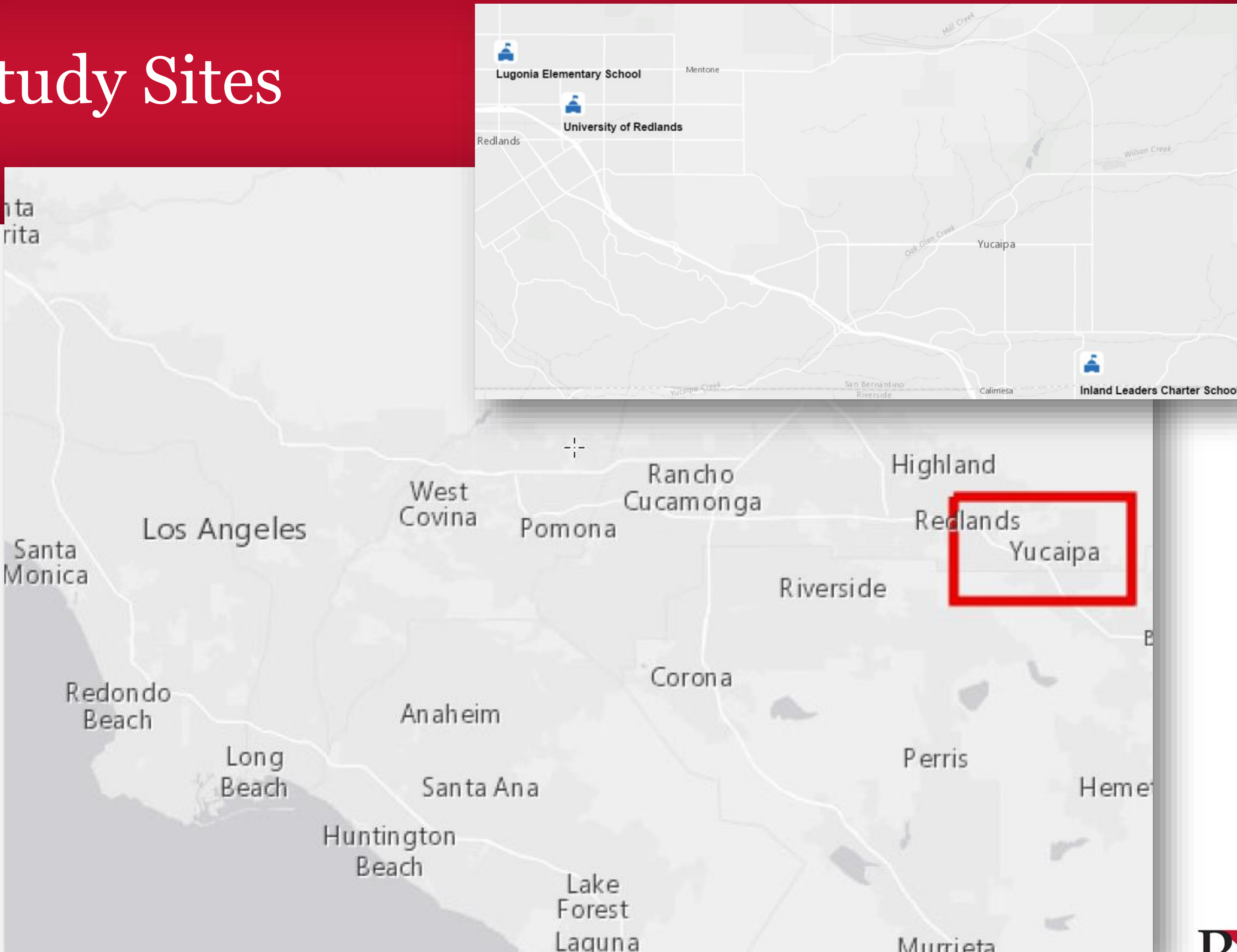
- Iteratively develop and evaluate supplemental instructional activities that build early computational skills in elementary-aged children.

Logic Model



Fundamental Spatial Thinking Skills
Impact
Computational Thinking Abilities
Which are Expressed Through
Mathematical Performance

Study Sites

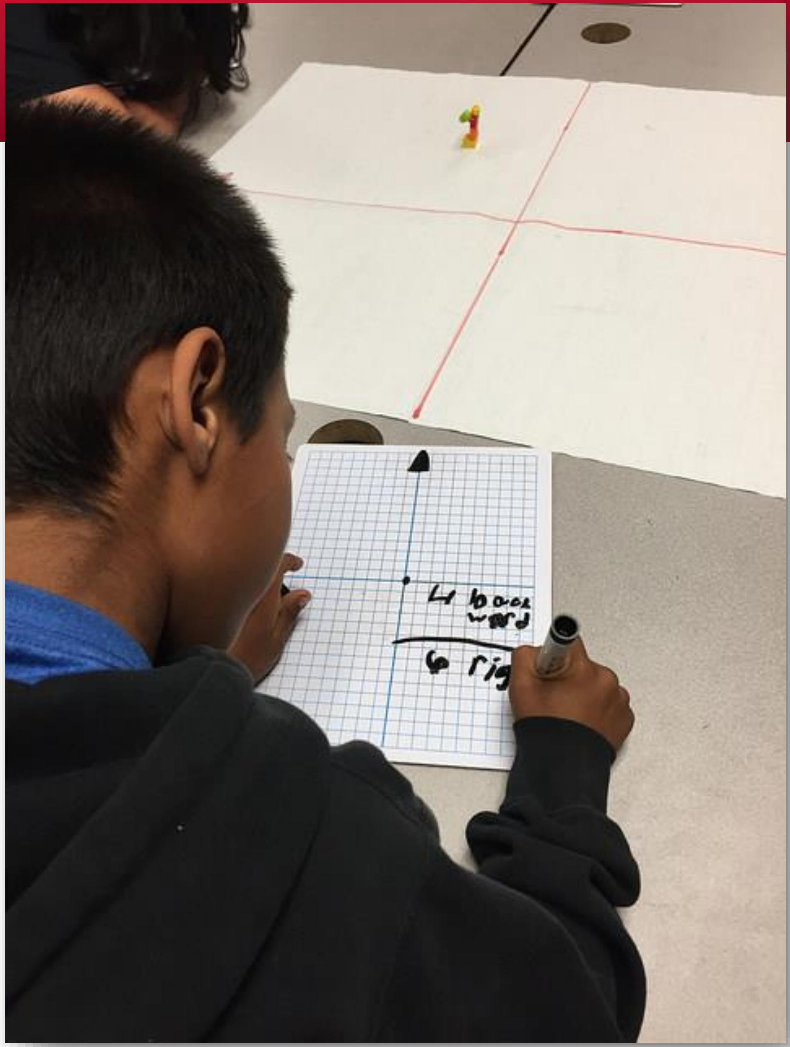


Lugonia Elementary School
Mentone
University of Redlands
Redlands
Yucaipa
Calimesa
Inland Leaders Charter School
Santa Monica
Los Angeles
West Covina
Pomona
Rancho Cucamonga
Highland
Redlands
Yucaipa
Riverside
Corona
Redondo Beach
Anaheim
Long Beach
Santa Ana
Perris
Huntington Beach
Lake Forest
Laguna
Murrieta

Approach

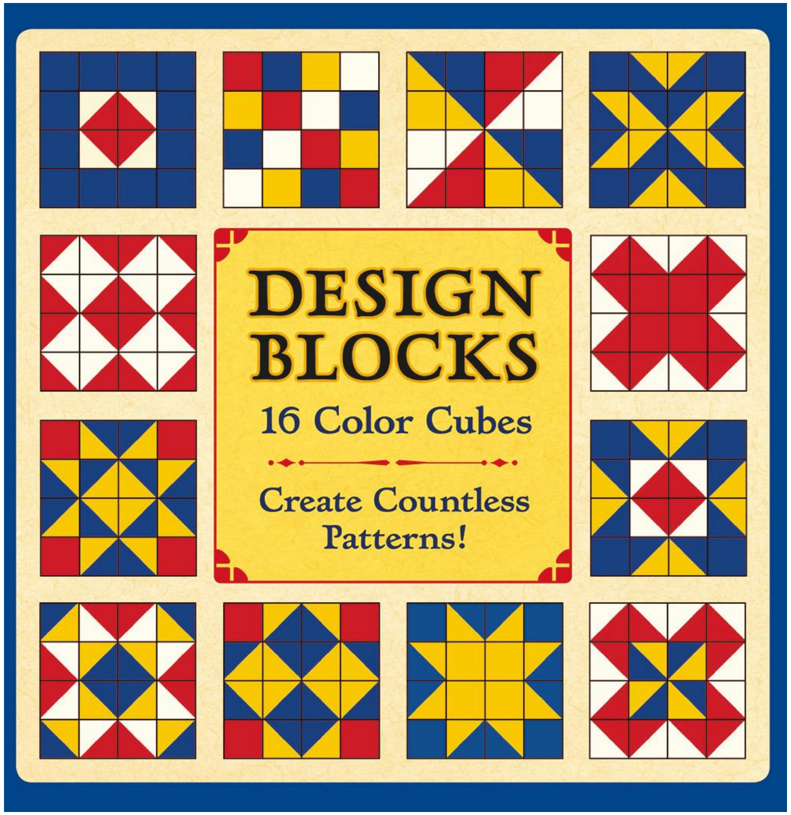
Implementing:

- Practical guided-inquiry activities
- Age-appropriate learning assessments



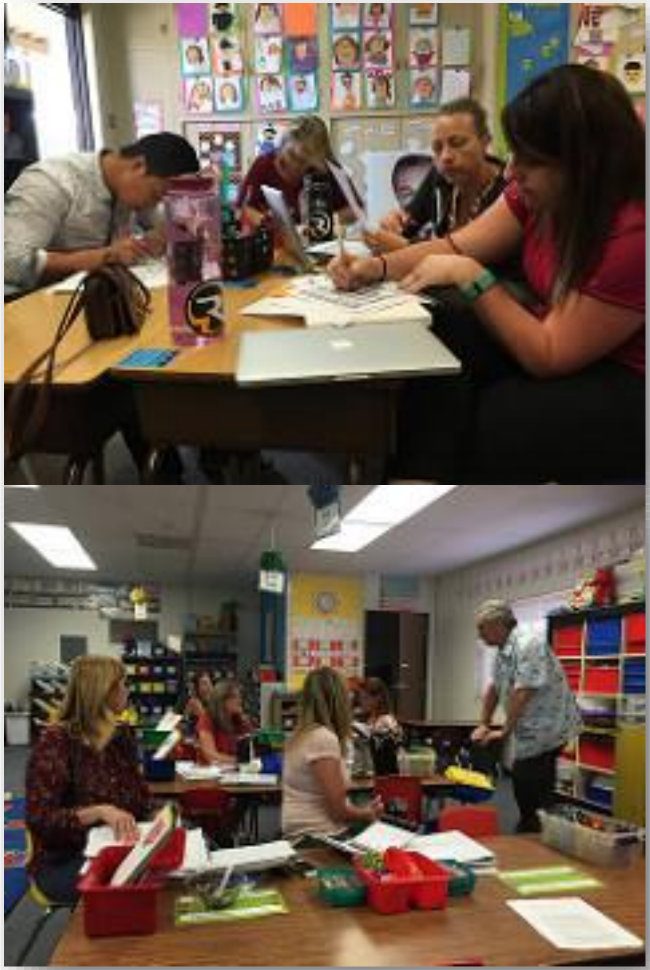
Supplies

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



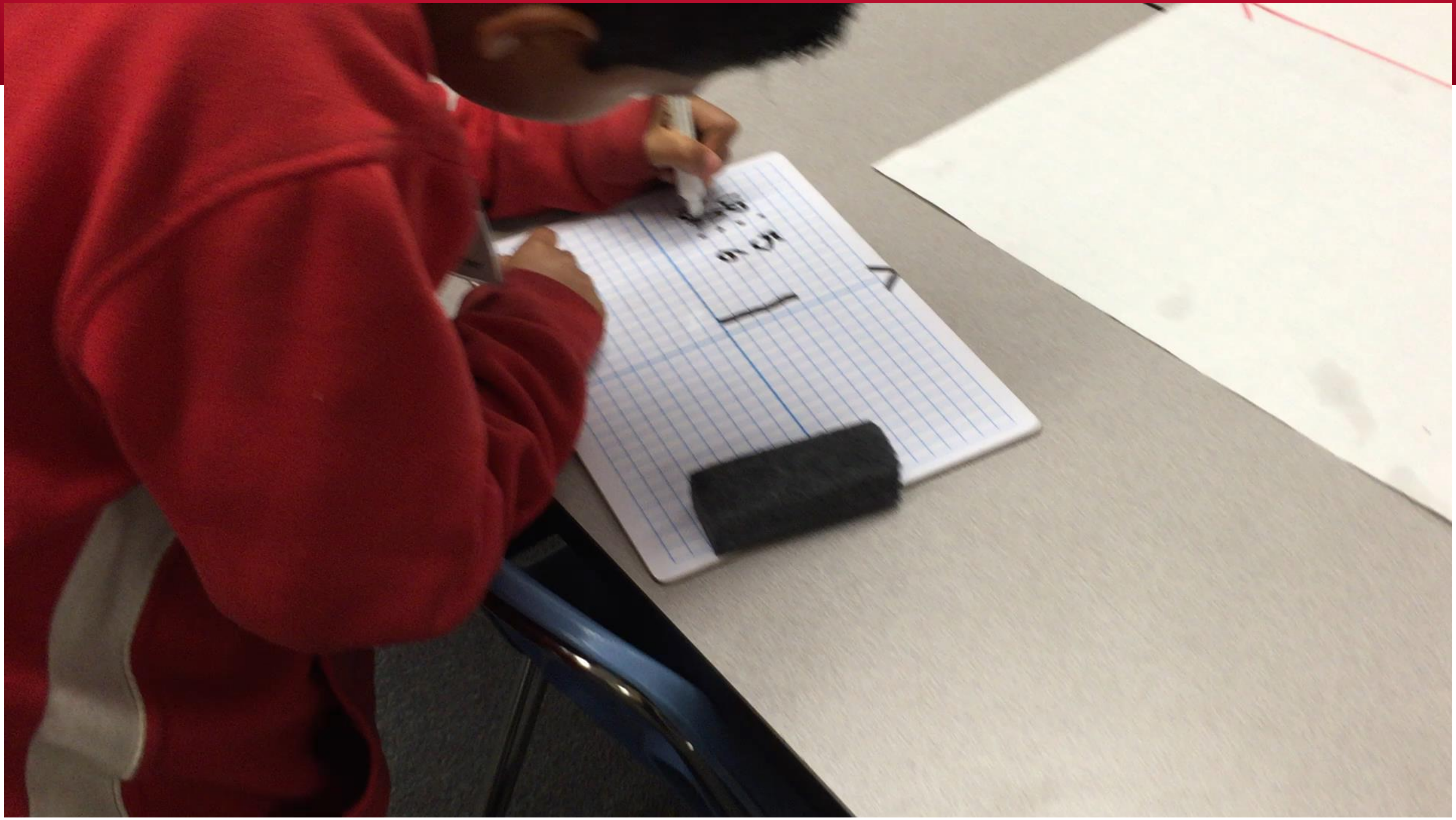
Design Teams

- Two teachers/grade level ("Involved Teachers")
- Biweekly meetings
- Highly collaborative
- Adaptive
- Personalized



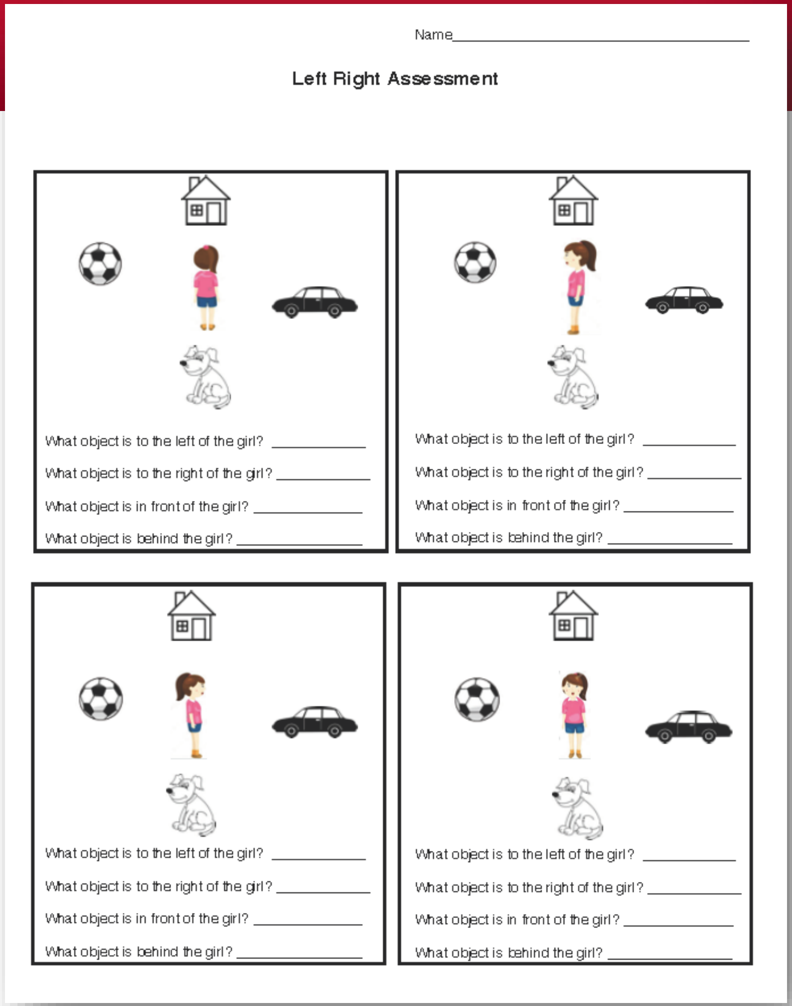
Classroom Example 1

Classroom Example 2



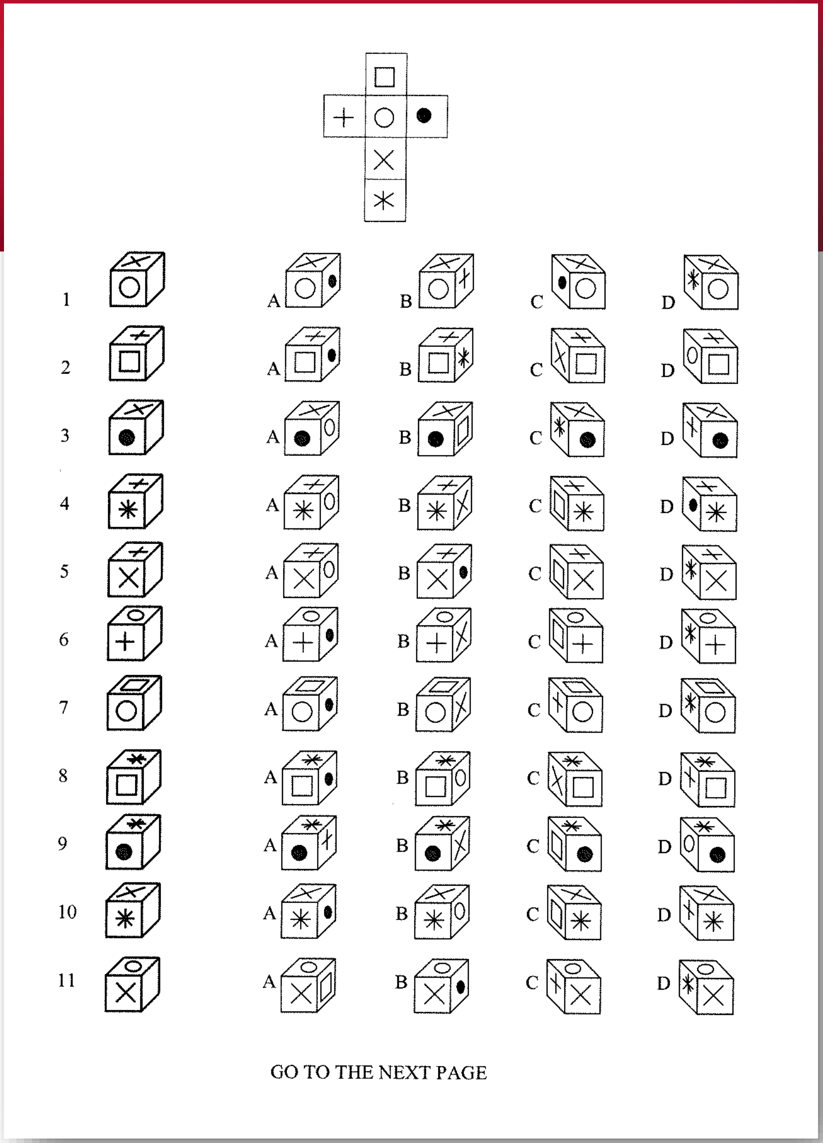
Assessments: K-2

- 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

Year 2 Timeline

1. Pre-Test Assessments
2. Classroom Implementation
3. Develop and Pilot Test Computational Thinking Assessment
4. Post-Test Assessments and Teacher Focus Groups
5. Data Analysis and eBook Production
6. Final Report and Dissemination of Results

Thanks

Advisors

- Pani Chakrapani, University of Redlands
- Cheryl Cohen, Veteran's Administration Information Resource Center
- David Uttal, Northwestern University

Partners

- Center for Educational Justice, University of Redlands
- Esri, Redlands, California
- Inland Leaders Charter School, Yucaipa, California
- Lugonia Elementary School, Redlands, California
- School of Education, University of Redlands

Evaluator

- Center for Evaluation and Educational Effectiveness (CEEE) at California State University, Long Beach

National Science Foundation

- STEM + Computing Partnerships (STEM+C) program

This material is based upon work supported by the National Science Foundation under Grant No. 1543204. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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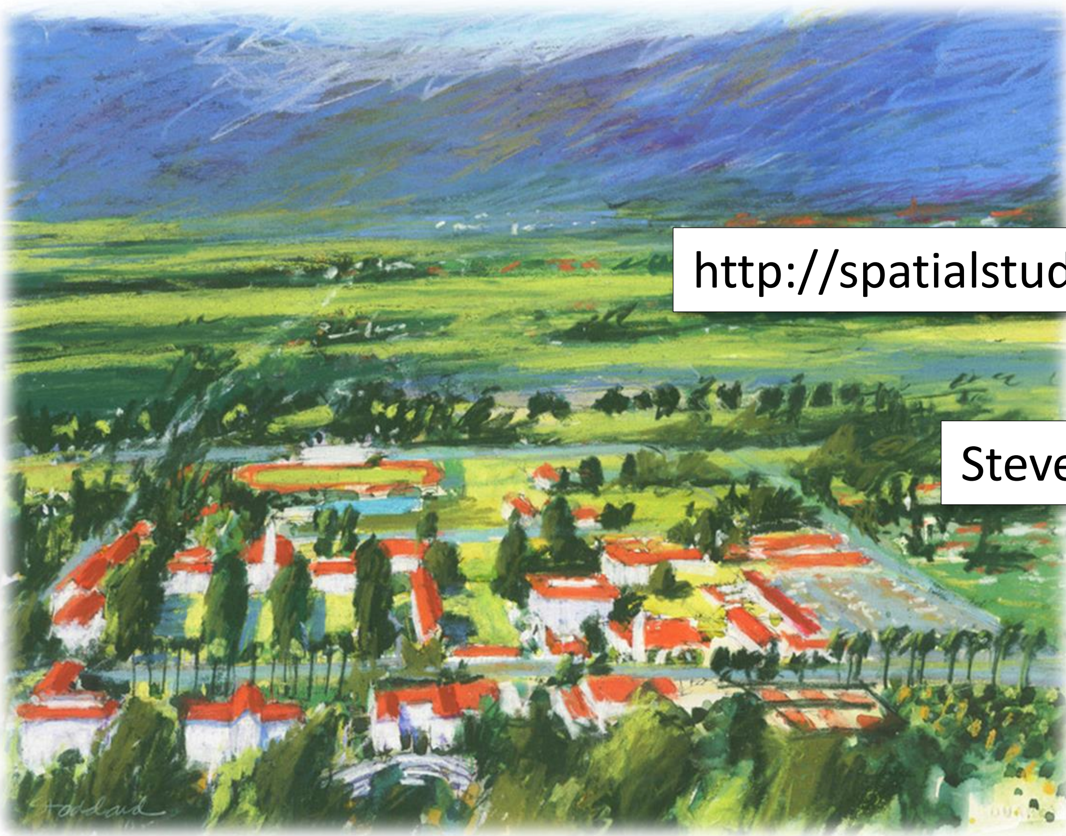

Center *for* Spatial Studies

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