Analysis of Spatial Concepts, Spatial Skills and Spatial representation in New York State Regents Earth Science Examinations

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Motivation for the Study and Research Questions

• Spatial Thinking is essential for geoscientists, so fostering and assessing is of interest to the geoscience education community

• What types of spatial thinking are evident in RES? How abundant are each in the exams?

• Are ‘spatial’ items more difficult than non-spatial items?
Goals

• Desire to motivate in- and pre-service teachers to attend more deliberately to fostering spatial thinking in instruction
• By-product: database of coded items that can be searched by topic and category to generate activities or assessments
• Strengthen student ability to think deeply about Earth processes, understand concepts
Target Audience ‘Live’/Publications

Earth2Class Workshops at LDEO

• 9 monthly programs focused on selected aspects of Spatial Thinking

• Feedback from teachers during and after each session

• 4 ‘practitioner’ articles and 1 ‘scholarly’ paper published to date
Context

- Spatial Thinking Is Important in Science, Especially Earth Science
- Spatial Performance Can Be Improved
- Spatial Thinking Is Undertaught in U.S. Schools
- The NYS ES Course and Exam is the largest population of students and teachers in the Nation (approx. 1 out of 5)
Methods

- Materials: PS/ES exams offered 3x a year
  84 or 85 written question (plus performance test—not included in the study)
  Used 12 then-recent exams/1,016 items

Exams relatively consistent in structure from year to year
Coding by Topic: Geosphere, Hydrosphere, Atmosphere, and Space

Coding by Spatial Thinking Attributes: Developed a set of coding categories, definitions, and examples, based on prior research and literature—3 broad categories

- Spatial concepts
- Spatial skills
- Spatial representation
Development and Affordances of the Database

• FileMaker Pro searchable database
• Used to generate data analyzed for Study and to develop hands-on activities around specific spatial thinking challenges for use in pilot PD program

• Available online through JGE article
Pilot Study of Spatial vs. Nonspatial Item Difficulty

• Feasibility study based on convenience sample, rather than statistically-rigorous data

• Presented to encourage future research, spur collection of data in archived format that will facilitate such studies
Results-Categories of Spatial Thinking
Spatial Concepts

- Position
- Configuration
- Distance
- Direction
- Motion
- Speed
- Trajectory
- Angle

- Size
- Volume
- Area
- Shape/morphology
- Cycle
- Texture
- Gradient
- Global intersection
Results-Categories of Spatial Thinking
Spatial Representations

- Map
- Cross-section/profile
- Block diagram
- Photograph
- Graph of Y vs. Distance
- Solar System Representation
- Other representations (dimensions represent dimensions of Earth system, such as Time Line)
Results-Categories of Spatial Thinking

Spatial Skills

- **Perspective taking** (how something looks from another viewpoint)
- **Mental animation** (how objects appear to move or deform)
- **Sequencing** (unravel the order of occurrence)
- **Describe** (account in own words)
- **Representational correspondence** (compare/contrast, combine from multiple images)
- **Visual penetrative ability** (envision inside of a volume when only outside is shown)
Abundance of Spatial Elements

Overall Abundance

• 63% (641 of 1,016 items in 12 exams) had at least one spatial element
• Similar in multiple-choice and constructed response
• Similar from test-to-test over year-to-year
• Most items contained more than one spatial subcode
Abundance of Spatial Elements by Geoscience Discipline

- Geoscience (Solid Earth): 49%
  (60% of such items are spatial)
- Space (Astronomy): 27%
  Most spatial—73%
- Atmosphere: 19%
  (63% are spatial)
- Hydrosphere: 5%
  Least spatial—53%
Abundance of Coded Spatial Elements

• Spatial Concepts
  configuration, position, motion, direction

• Spatial Representation
  Occur in the item prompt
  Occur in the answer booklet
  Occur on the Earth Science Reference Tables

• Spatial Skill
  Mental animation, representational correspondence, perspective taking
  Sequencing on every exam
  Visual penetrative ability rarely assessed
Difficulty of Spatial Elements

In our limited sample of student results:
Mean % correct for spatial: 66%
Mean % correct for non-spatial: 73%

Items with lowest % correct: 9 out of 10 spatial

More difficult: gradient, trajectory, perspective taking, describing, solar system representations
Discussion

• Abundance across all exams confirms urgency of attention to spatial thinking in planning and implementing ES instruction
• Creation and vetting system is effective in producing exams that test for spatial concepts, skills, and representation
• Product of ‘social construction created by a community of practice sharing a common set of values’
Discussion, cont’d.

• Distribution of topics not focus of study, but interesting:
  50% Solid Earth
  25% Astronomy
  25% Fluid Earth (Atmosphere & Hydrosphere)

• ‘Quantitative’ concepts (distance, angle, speed, gradient, etc.) less abundant → qualitative approach used in most precollege instruction
Discussion, cont’d

• Maps, profiles, and cross-sections are tools often used by geoscientists to examine causally significant patterns of ‘trading space for time’
• Mental animation reflects prominence of dynamic processes in geosciences
• Representational correspondence abundance reflects types of skills in elementary geography
How to Apply These Findings to Improve Earth Science Education

• ESRT can serve as model to move forward in developing assessments aligned with NGSS and Framework
  “obtain, evaluate, communicate information”

• Motivate to be more attentive and explicit about spatial thinking in instruction and assessment
Applying the Findings, cont’d

• NYS expressed intention to move toward data-informed model for school improvement

• Future patterns may reveal students of some teachers to well in some kinds of items and poorly in others

• Consequence: Professional development could support teachers whose students exhibit difficulties in certain topics and skills
‘Take-Away’

• More than ‘teaching to the test’
• Spatial concepts, skills, representation abound in geosciences, and geoscience-related examples abound in everyday Life
• Improving spatial proficiency will benefit students well beyond any single course or test