Spatial Thinking in the New York State High School Earth Science Exam

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From 1941 Earth Science Regents exam
Professional Development to Improve the Spatial Thinking of Earth Science Teachers and Students

• Analyze released New York State Earth Science Regents exam items for spatial thinking:
  • What is abundant?
  • What is hard?

• Pilot and evaluate a professional development program for Earth Science teachers piggy-backing on Earth2class

• Expand spatial thinking professional development statewide and nationwide (?), leveraging move towards data-driven PD
New York State Earth Science Regents Exam

- Year-long course: covers solid earth, atmosphere, oceans & space
- Usually taken in 8th or 9th grade
- Requires laboratory (1200 minutes)

- Three hour exam
- Given since 1941; all items released
- 50 multiple choice + 34 or 35 constructed response
- Taken by 160,000+ students per year
“Finding the Spatial” in Earth Science Regents Course

Physical Setting/
Earth Science
Core Curriculum
New York Earth Science Reference Tables

16 page booklet
“Finding the Spatial” in Earth Science Regents Exams

• Began with a holistic definition: “… thinking that finds meaning in the shape, size, orientation, location, direction or trajectory of objects, processes, or phenomena … or the relative positions in space of multiple objects, processes, or phenomena.“

• Saturday work session with teachers: what did they think was spatial in the Earth Science Regents?

• Initial classification into spatial/non-spatial

• Gradual articulation of sub-categories:
  • Spatial concepts
  • Spatial representations
  • Spatial skills
“Finding the Spatial” in Earth Science Regents Exams (2)

- Eleven exams coded: Jan 2008 through June 2011
- 931 items
- All items coded independently by Kastens and Pistolesi; differences reconciled by discussion
- Inter-rater consistency is 89.5% for spatial/non-spatial
- Biggest challenge was agreeing on exclusion criteria for trivially-spatial items. Item must require thinking as well as spatialness.
Spatial thinking is abundant in Regents Earth Science Exam

- 63.6 % of all questions
- 63.3 % of the multiple choice questions
- 64.0 % of the constructed response questions
Frequency of Spatial Concepts

97% of spatial items
Configuration (SC-Cn)

The map below shows the names and ages of different bedrock formations in North America. The bedrock ages are shown in billions of years.

...relative position of two or more objects, attributes or phenomena...

The ages shown on the map suggest that the
(1) oldest bedrock is located in the Churchill formation
(2) youngest bedrock is located in the Wyoming formation
(3) younger bedrock has been added to the east and west coasts of the continent
(4) age of bedrock increases from west to east across the continent
Frequency of Spatial Representations

- 72% of spatial items
  - on item prompt
  - on answer sheet
  - on Earth Science Reference Table

Graph showing the frequency of spatial representations with categories: Map, Profile, Solar System, Other, Photograph.
17 In which New York State landscape region have fossilized footprints of *Coelophysis* dinosaurs been found in the surface bedrock?

(1) Allegheny Plateau  
(2) Tug Hill Plateau  
(3) Hudson-Mohawk Lowlands  
(4) Newark Lowlands

Timeline -> Bedrock geology map -> Landscape regions map
Frequency of Spatial Skills subcodes:

- Mental Animation: 52% of spatial items
- Represent. Correspond.: 10% of spatial items
- Perspective Taking: 5% of spatial items
- Describe: 5% of spatial items
- Sequence: 0% of spatial items
- Visual Penetrat. Abil.: 0% of spatial items
Mental animation (SS-MA)

2. A camera was placed in an open field and pointed toward the northern sky. The lens of the camera was left open for a certain amount of time. The result is shown in the photograph below. The angle of the arc through which two of the stars appeared to move during this time exposure is shown.

Student needs to or would benefit from envisioning that objects are moving or deforming and how they are moving or deforming...

How many hours was the lens left open to produce the photograph?

(1) 12  (3) 6
(2) 2    (4) 4
Visual Penetrative Ability is very minor (<1% of items)


Draw the vertical cross-section between A and B.
Difficulty of spatial versus non-spatial items

- 26 school districts in one BOCES region
- One exam (June 2010)

Mean of Spatial items = 66% correct
Mean of Non-spatial items = 73% correct

12 out of the 13 hardest items are spatial
Difficulty of spatial versus non-spatial categories

- Hardest Spatial Concepts
  - Trajectory (14 percentage points worse than average spatial item)
  - Gradient (5 points worse)

- Hardest Spatial Representation
  - Solar System (9 points worse)

- Hardest Spatial Skills
  - Describe spatial phenomena (5 points worse)
  - Perspective taking (4 points worse)
The diagram below shows the Moon at four positions in its orbit around Earth as viewed from above the North Pole. The date of one of the four positions has been labeled.

Which photograph shows the appearance of the Moon as viewed by an obse New York State on May 17, 2000?
79 Explain why the type of rock changes between locations B and C. [1]

Allowed answers:

- Heat and pressure increase from B to C.
- Regional metamorphism is greatest at C.
- Different grades of metamorphism

SC: Gradient
SC: Position
SC: Configuration
SR: Profile
SS: Describe
The map below shows four watershed regions in New York State labeled A through D.

Which lettered section represents the watershed of the Mohawk and Hudson Rivers?

- (1) A
- (2) B
- (3) C
- (4) D
Conclusions

• A wide range of spatial concepts, spatial representations, and spatial skills are being assessed on the Earth Science Regents.

• Configuration, position, motion and direction are the most frequently assessed spatial concepts.

• Mental animation and representational correspondence are the most frequently assessed spatial skills.

• Earth Science Reference Tables enable more challenging questions using spatial representations, especially maps & profiles.

• Spatial questions are more difficult than non-spatial questions for students.

• Questions involving gradient, trajectory, and solar system diagrams are the most difficult (in a limited data set).
Next Steps

In progress: Pilot and evaluate professional development on spatial thinking for local Earth Science teachers

Dream: Expand spatial thinking professional development statewide and nationwide (?), leveraging movement towards “data-driven” PD.