The Role of Basic Spatial Concepts in Education: What Learners Bring to the Classroom

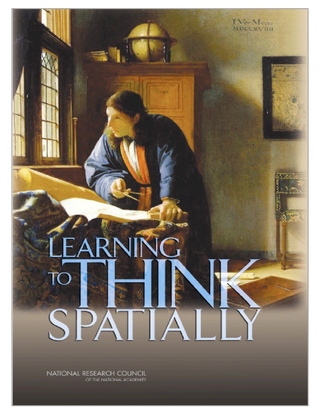
Lynn S. Liben[a] Kim A. Kastens[b] & Adam E. Christensen[a]

[a]The Pennsylvania State University (Department of Psychology); [b]Columbia University (Lamont-Doherty Earth Observatory, Department of Earth & Environmental Sciences)

Background

Importance of Spatial Thinking in Science

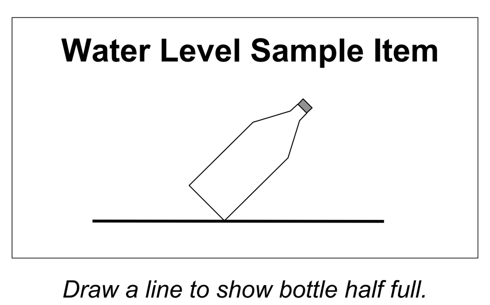
Spatial thinking is a core cognitive domain. It has been increasingly recognized as critical for science and math education, e.g., the recent NRC report on *Learning to Think Spatially*

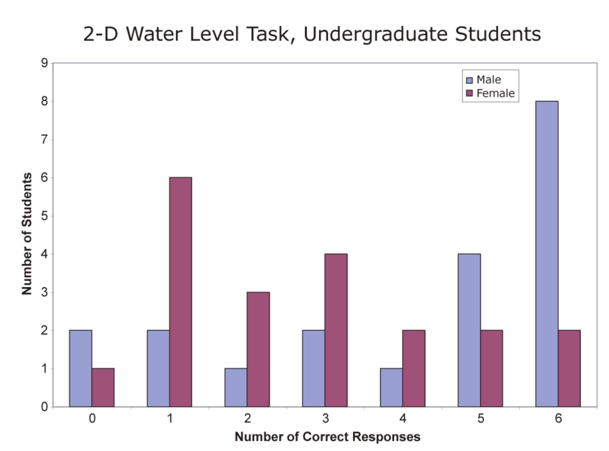


Spatial Concepts

Many students – from kindergarteners to undergraduates – have trouble with even basic spatial concepts such as understanding Euclidean horizontal and vertical coordinate axes.

Illustrative is research on the "water level task" (WLT) showing that many college students (especially females) have difficulty representing the invariant horizontality of liquid.





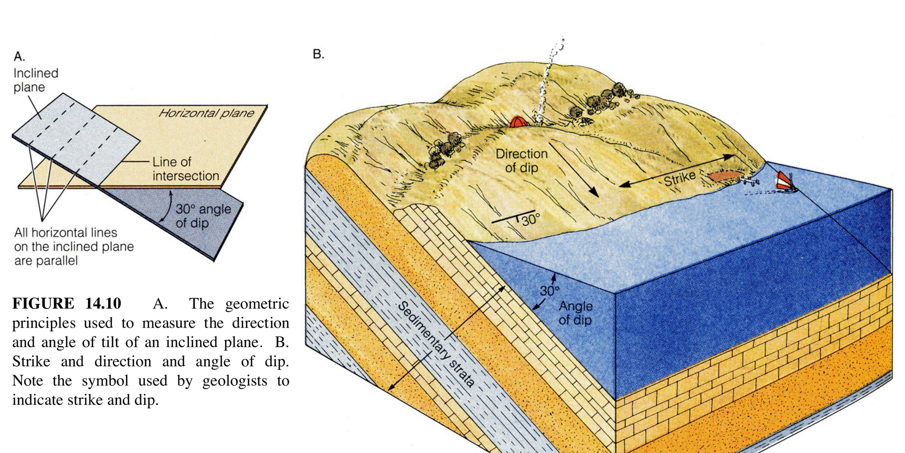
Spatial Thinking in Geology

We hypothesized that these spatial concepts are needed by field geologists as they observe and record on a map rock outcrops' strike and dip.

Strike is the line at the intersection between the horizontal plane and the plane of the rock surface, recorded by a line on a map.

Dip is the angle between the horizontal plane and the plane of the rock surface, measured within the vertical plane.

Textbook illustration showing relevance of horizontality and verticality for strike & dip



From Skinner et al., 1995, *The Dynamic Earth.*

Study 1

Study 1 was designed to study whether college students who have difficulty on the WLT also have difficulty learning strike and dip.

Participants

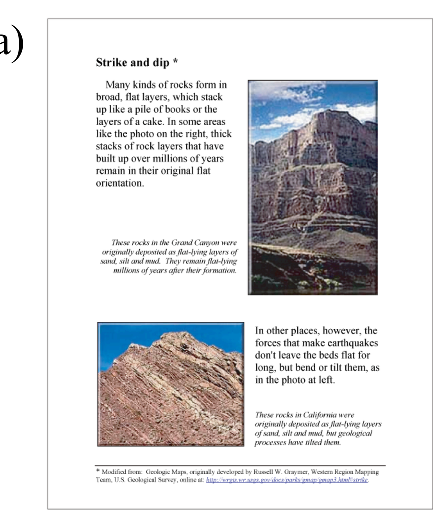
We screened roughly 600 undergraduates enrolled in introductory psychology courses for their understanding of horizontality on a 6-item WLT. Males and females from each of the following WL Groups (~20/cell; N = 125) were then given geology instruction.

High WLG:	all 6 water lines correct
Medium WLG:	mixed correct & incorrect
Low WLG:	all 6 water lines incorrect

Geology Instructions & Tasks

- Students were given instructions (a) on strike and dip based on US Geological Survey explanations.
- Students were taken to an artificial outcrop made of plywood, similar to that shown in (b), and installed in a sloping area near a campus building (c).

(a)



(b)

(c)

- Students were asked to draw the strike line on a map of the nearby area of campus (d), to show dip direction, and to estimate dip in degrees.
- They were also asked to draw a line on another copy of the same map to indicate the orientation of a rod (e).

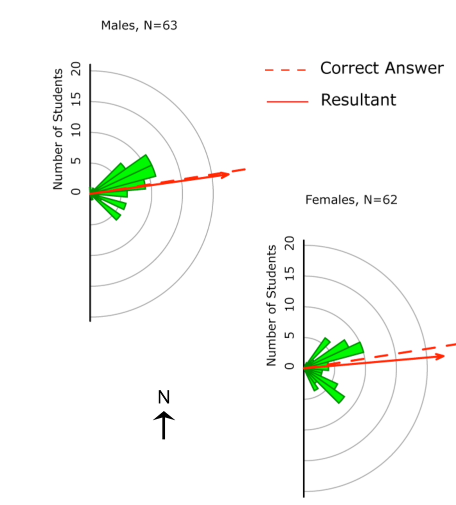
(d)

(e)

Key Findings: Study 1

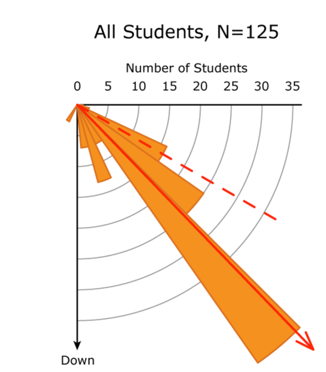
Strike Lines

- Students varied greatly in their success in orienting the strike line on the map correctly. 41% of lines were off by 30° or more. Many students seemed to be recording the long axis of outcrop rather than strike. Males' errors, 24° were significantly smaller than females', 31°.



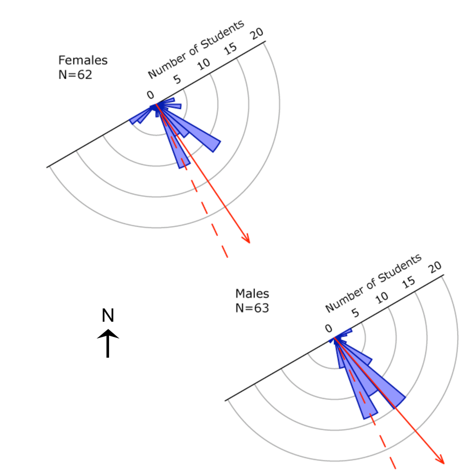
Dip Lines & Numbers

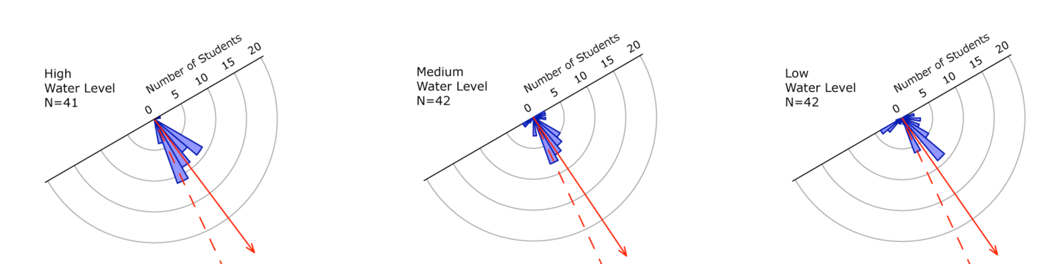
- Students generally over-estimated dip by 20°. The modal response was 45° (correct: 30°). Some gave impossible responses of over 90°.



Rod Lines

- Again, performance was highly variable, with 34% deviating from correct by 30° or more. On rod, performance differed both by sex (right), males' error, 24° females' error 43° and WLG (below), high, medium, low, respectively: 15°, 36°, 49°





Study 2

Study 2 was designed to pinpoint students' difficulties by simplifying tasks to remove challenges we judged peripheral to core spatial concepts. Again, we enrolled students based on WLT scores (N = 94).

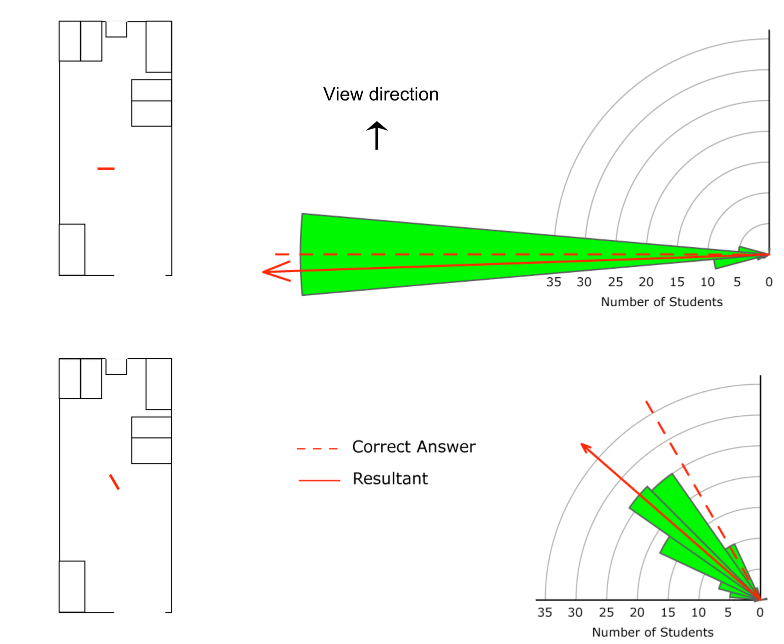
Task Modifications

- Tasks were given indoors (simpler, smaller, more rectilinear environment); model/small rod on a table replaced buried outcrop/large rod outside.

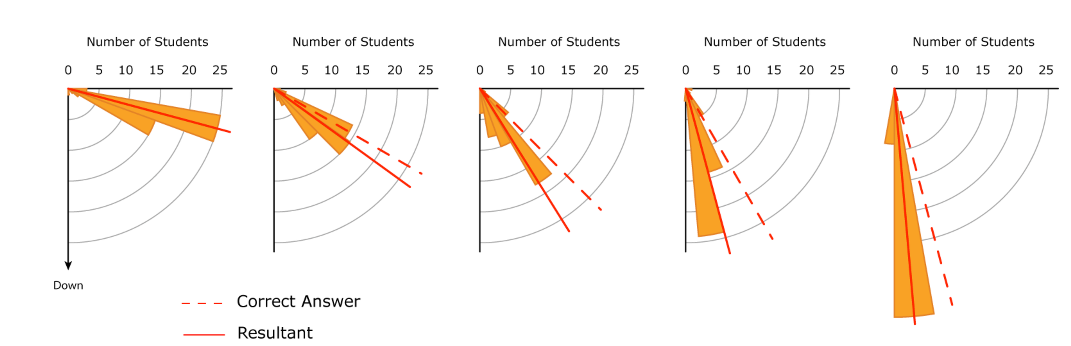
- Horizontal (strike) lines were drawn on models and direct instructions ("*draw a line on the map to show the location and direction of this line/rod*") were substituted for geology instructions. 8 rod, 8 strike, and 5 dip.

Key Findings: Study 2

- Although performance was far better than in Study 1, it remained far from ceiling. Errors were greater on strike (13°) than rod (7°) and were lower when correct lines paralleled walls' axes (see samples).



- As expected, strike errors were smaller in the high WLG than in low WLG (11° vs. 15°). Furthermore, medium and low WLG did worse on strike if it was first.
- Dip data – as in Study 1 – showed systematic *overestimates* of the steepness of the (model) outcrops. These data fit Proffitt's (2006) finding that adults overestimate hills' inclines.



Conclusions

The data suggest that educators should not presume that all students arrive at their classrooms with the basic spatial skills needed to understand and represent phenomena central to many science disciplines. Additional research is needed to test the potential value of providing instruction in basic spatial skills as a foundation on which to build science education.

Acknowledgments

This research was supported by NSF Grants to Liben and Kastens, REC #04-11686 and #04-11823, respectively. The opinions are those of the authors, and no endorsement by NSF should be inferred. Correspondence may be addressed to liben@psu.edu.