GIS Analysis of Spatial Conceptions in Introductory Geology: Engaging Students with Diagrams using Clickers

Emma Falk[1], Nicole LaDue[2], Thomas F. Shipley[3], & Glenn Dolphin[4]

[1]Department of Geography and Atmospheric Sciences, Northern Illinois University, DeKalb IL [2]Department of Geology and Environmental Geosciences, Northern Illinois University, DeKalb IL;
[3]Department of Psychology, Temple University, Philadelphia, PA; [4]Department of Geoscience, University of Calgary, Calgary, Canada

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Introduction

Students struggle to interpret diagrams in introductory geology courses because they are visually complex and represent spatially challenging concepts. This study examines non-science majors' spatial thinking patterns and conceptual challenges in an introductory geology course. We compare pre-course to end-of-course performance on diagram reasoning tasks, via clicker question responses.

In Spring of 2019, 126 undergraduate students enrolled in an introductory geology course at a large Canadian university consented to participate in this research study and completed the pre-and end-of-course questions using the Top Hat classroom response system. Student responses for each questions are plotted on the diagram using ArcGIS. Regions of correct and incorrect responses are identified using polygons. There are significant differences in pre-course and end-of-course responses, identified through Chi-square analysis.

This study demonstrates that clickers are a useful tool for documenting learning. Instructors can use the Top Hat heat map feature to qualitatively observe differences in students pre- and end-of-course responses, and ArcGIS analysis can identify common, alternative, and incorrect responses for research purposes.

Background

Studies report that students' conceptions may be easily revised or difficult to change because they require an ontological category shift.[1]

Most research on students' conceptions involves time-consuming interview data collection and analysis.[2]

This study utilizes a common classroom response system, Top Hat, to gather students' conceptions associated with common geologic diagrams and processes. This builds upon research that demonstrates students conceptual challenges with diagrams occupy the following spatial categories:[3]

Spatial Integration: Combining observations to construct an explanation (ex. River erosion, correlation)

Scalar Relationships: Identifying the relative or absolute position of a feature within an object or describing an event (ex. Geologic time)

Spatial Frame of Reference: Evaluating the position of an object or feature relative to an object or the environment (ex. Lateral continuity, hot spots)

Methods

"Click where you expect humans appeared on Earth."

Pre-Instruction **End-of-Course**

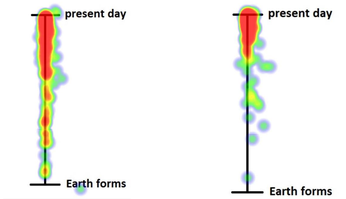
1. Sample Population

126 undergraduate non-geology majors

Top Hat Clicker Questions

Pre-instruction & End-of Course

Top Hat Generated Heat Maps

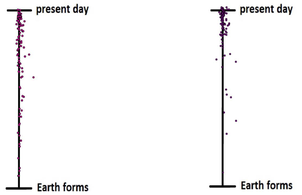


2. Plotting in GIS

X-Y coordinates of student clicks in Top Hat

Plot in ArcGIS:
- Import jpgs
- Control point layer for georeferencing
- Plot data points

ArcGIS Plotted Student Clicks



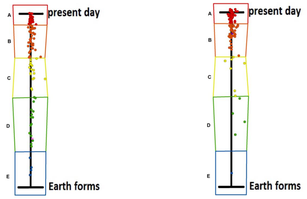
3. Choosing Polygons

Select regions of similar response groups

Draw polygons

Select data by polygons

ArcGIS Polygons of Common Responses



4. Statistical Analysis

Counts of students within correct versus incorrect polygons

Chi-square statistic to test for significance

		Responses			
		Incorrect	Correct	X^2	Φ
Human Appearance on Earth	Pre-	81	44	11.74**	0.22
	End-	54	71		

** p<0.001

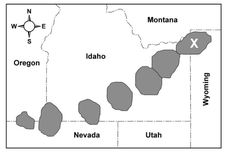
Effect size: Φ = √(X2/n)

.1 = small effect
.3 = medium effect
.5 = large effect

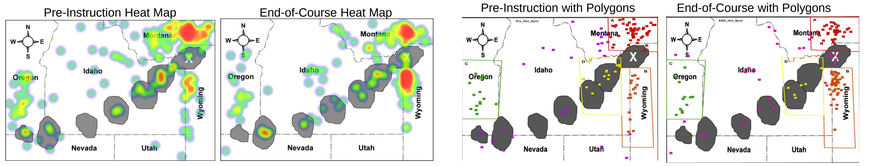
Results

Hot Spots Relative to Plate Movement

"The North American tectonic plate has moved south west over the Yellowstone hot spot. If the plate started moving north, click where you expect the next volcanic caldera will form."



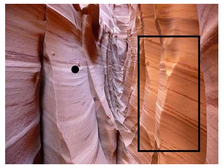
Spatial Frame of Reference



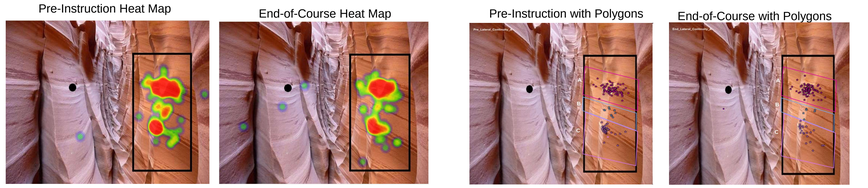
X^2 (1, N=198) = 20.02, p<0.0001, Φ=0.32

Lateral Continuity

"Click in the box where you find the same layer as the one labeled with a dot."



Spatial Frame of Reference

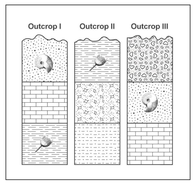


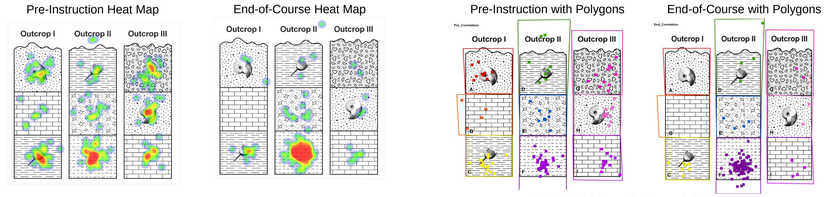
X^2 (1, N=240) = 2.28, n.s.

Spatial Integration

Correlation

"Fossils and rock types are evidence used to correlate rocks across great distances. By matching the outcrops below, click on the layer that is the oldest layer of all three outcrops."

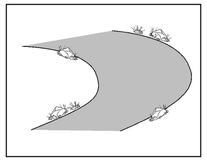


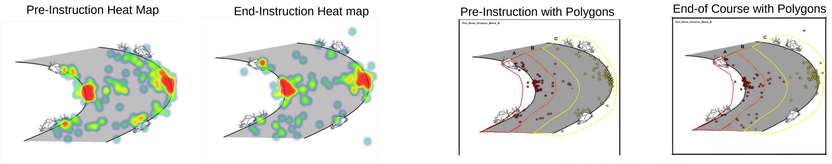


X^2 (1, N=262) = 59.52, p<0.001, Φ=0.49

Erosion in a River Bend

"Click in the river where you expect to find the greatest rate of erosion."

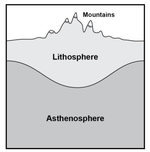


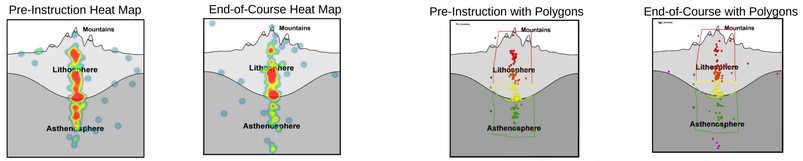


X^2 (1, N=213) = 0.03, n.s.

Isostasy

"Click where you expect to find the bottom of the lithosphere after the mountains have eroded away."





X^2 (1, N=234) = 6.41, p<0.01, Φ=0.17

Conclusions

This study provides evidence that clicker questions may reveal students conceptual challenges. Top Hat is an excellent tool for this type of research. ArcGIS can be used to select high density regions of student responses and identify which students selected correct versus incorrect regions. Relevant to this study, we see significant improvement in questions related to:

- Spatial Frame of Reference: hot spots,
- Scalar Relationships: Geologic Time
- Spatial Integration: correlation and isostasy.

Growth was not observed in the lateral continuity or erosion in a river bend questions, likely because these two topics were not covered in the course.

Limitations

Top Hat is proprietary and students pay for the service. Alternative tools for instruction include PollEverywhere. We are currently testing Qualtrics as an alternative research tool, as it offers the same data output as Top Hat (i.e., x-y coordinates of clicks.)

The conceptual challenges observe here need to be verified through qualtitative data collection to understand the cause and nature of conceptual errors. Next steps include a mixed-methods approach.

References:
[1]Chi, M.T.H. (2008). Three types of conceptual change: Belief revision, mental model transformation, and categorical shift. In S. Vosniadou (Ed.), Handbook of research on conceptual change (pp. 61-82). Hillsdale, NJ: Erlbaum. [2]Cheek, K. A. (2010). Commentary: A summary and analysis of twenty-seven years of geoscience conceptions research. Journal of Geoscience Education, 58(3), 122-134. [3]LaDue, N. D., & Shipley, T. F. (2018). Click-On-Diagram Questions: a New Tool to Study Conceptions Using Classroom Response Systems. Journal of Science Education and Technology, 27(6), 492-507.

Acknowledgements

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Seeking Post-doc and Grad Student

If this research interests you, consider applying for a post-doctoral fellowship or graduate assistantship with the NIU Visualization & Geoscience Education Research Lab. Funding is available now. Inquiry with Dr. Nicole LaDue: nladue@niu.edu