The Power of an Interdisciplinary Approach: Bringing together the expertise we need to build stronger tools for visual communication in geoscience.

Cathy Manduca

Why am I interested in ' Teaching with Visualizations'?

Over the past several years, there has been increasing interest in creating visualizations for both scientific research and teaching in all of the sciences. This reflects the power of visualization tools in our research and the excitement we have for seeing our mental images of scientific processes captured on a computer screen. It is no wonder we are excited to use visualizations in our teaching. My interest in bringing together geoscience educators, learning scientists, and creators of visualizations comes from the convergence of four observations:

1) Faculty are really interested in using animations in their teaching. I often ask faculty what kinds of resources would be helpful to them, and frequently the answer is a library of animations. I would like to capitalize on this interest in using animations to help faculty be better teachers. This means providing them with access to "good" visualizations and help for how to use them effectively.
2) Research exploring the benefits of animations (Tversky, 2002) and the ways we learn from symbols (Uttal, 2002) contradicts our intuition about effective visualizations. Animations that are completely clear to geoscientists and capture all they know about an earth process may not be conveying the same information to students learning the topic and may not be very helpful. Further, creating symbols for objects that are too similar to the objects themselves may cause confusion – that is, diagrams depicting earth processes in a schematic way may be more confusing as the components in the diagram become more realistic.
3) Our science increasingly uses visualizations to display and interpret data, but we know very little about what either scientists or students are "seeing" when they interpret these visualizations. I was particularly struck by my own experience with the climate model visualization created by Don Middleton at NCAR that is displayed in our workshop website banner. When I saw this visualization for the first time, I felt that it answered many questions that I had about global atmospheric circulation. I had a very strong feeling of learning and understanding. However, when I thought carefully, I realized I didn't even know what the colors in the visualization represented. Was my new understanding correct or did I jump to an erroneous conclusion about what I was seeing? Given this power of visualizations to communicate we must learn to design and use them wisely so that we avoid misunderstandings. In my mind, this care is equally important for visualizations that enable scientists to communicate among one another as it is for teaching and communicating with the public.
4) Discussions about teaching and learning geoscience call out the importance of observation and making mental visualizations (e.g. Manduca, Mogk and Stillings, 2004). This resonates with my experience as a field geologist where I spent years making maps as an aid to developing my own complete three-dimensional mental

animation of the evolution of the geology of my field area through time with an integrated geographically referenced chemical data-set. This mental animation including the geochemical data was used to create and test theories about the origin and evolution of the rocks I was studying. Thus, I am particularly interested in what research on learning can tell us about how geoscientists use mental visualization and how we can assist students in gaining this skill. This information is particularly important as we discuss the future of field training in our discipline and take advantage of new opportunities to engage students with data.

Summing up these ideas, a major opportunity exists to enhance geoscience education through the effective use of visualizations because faculty are excited by animations that capture their knowledge of a topic and by visualizations that are powerful in their work as scientists. However, to effectively capitalize on the use of visualizations in teaching and research we need to know much more about how people learn from visualizations, how they develop their own mental visualizations, and how to design visualizations to effectively teach geoscience concepts.

How does this workshop build on past work?
The focus of my work is on improving geoscience education for undergraduates. My tools have primarily been conferences, reports, professional society meetings, and websites. In 1996, Frank Ireton, Dave Mogk, and I brought together geoscience educators from geology, ocean science and atmospheric science to consider the importance of working together to teach undergraduates about the complete Earth system and to outline the major challenges facing the discipline. The resulting report "Shaping the Future of Undergraduate Earth Science Education—Innovation and Change Using an Earth System Approach" (Ireton et al, 1997) articulates many of the high level goals of geoscience education while making recommendations for teaching strategies and ways to address other ongoing issues critical to improving student learning.

The focus on goals for geoscience education recurred as a major theme at the 2002 workshop "Bringing Research on Learning to the Geosciences" convened by Dave Mogk, Neil Stillings and myself. This workshop brought together leaders from geoscience education, learning science, and the application of learning science to specific science disciplines to initiate the development of a community engaged in applying learning science to the geosciences. The report from this workshop (serc.carleton.edu/research_on_learning/workshop02) outlines a three part strategy including research, dissemination and professional development to enhance geoscience learning by applying the results of research. A critical piece of the proposed research is the development of an understanding of geoscience expertise that can be used to establish well-articulated goals for geoscience education both at the level of the discipline, and by individual faculty in the design of their courses. Research is also recommended that addresses how students acquire geoscience expertise and the design of effective instructional environments.

The important role of observation and visualization in the practice of geoscience and in geoscience expertise was called out at the workshop. These fundamental skills underlie the ability of geoscientists to make sense of field observations, as well as of direct and remote observations on a wide variety of spatial scales, and of complex data sets. Workshop participants recommended increased research into the role of visualization in geoscience thinking and the use of visualizations in teaching. Our current workshop, "Teaching Geoscience with Visualizations" workshop is an exciting response to recommendations in the Bringing Research on Learning to the Geosciences report.

One of the major uses of visualizations in geoscience research and teaching is in displaying data: global observational data, calculated data from models, geographically referenced observations of multiple types (GIS data), representations of the chemical compositions of various earth materials, among others. To explore how faculty across the sciences teach with data and why they think it is important, Dave Mogk and I convened an interdisciplinary workshop and produced the subsequent report "Using Data in the Classroom" (serc.carleton.edu/usingdata). This report again returns to the idea of goals. By considering what we want our students to learn from their experiences with data, the workshop participants developed a set of recommendations for what students should be able to do with data that provide guidance for the developers of data services. These goals and recommendations are helpful as we discuss our use of visualizations in helping students explore and understand data.

This workshop provides for me an opportunity to build on earlier work by considering more specifically the research and questions surrounding teaching with visualizations. I believe that by working in this focused area of high interest, we can demonstrate how by bringing together expertise in geoscience, learning, and education with technical expertise we can improve our ability to do science, to communicate science and to teach science. Of particular interest are articulating principles that can help both developers and users of visualizations be more effective in their work; strategies that can help faculty understand what we know about effective use of visualizations; and research that can refine that understanding. My particular strength will be in assisting with dissemination and professional development, but I am equally excited to begin to engage the research questions, particularly in ways that involve broad community participation.

Acknowledgements

The National Science Foundation provided funding for all of the conferences and reports described above. In addition, "Bringing Research on Learning to the Geosciences" was hosted by the Johnson Foundation at the Wingspread Conference Center. The American Geophysical Union sponsored the "Shaping the Future" conference and published the report. The National Science Digital Library Core Integration Service sponsored the "Using Data in the Classroom" conference.

References

Ireton, M.F.W., Manduca, C.A., and Mogk, D.W. eds., 1997, Shaping the Future of Undergraduate Earth Science Education-Innovation and Change Using an Earth System Approach, American Geophysical Union, Washington, DC.
http://www.agu.org/sci_soc/educ.html#Shaping

Manduca, C.A., Mogk, D.W., Stillings,N., 2002, Bringing Research on Learning to the Earth Sciences: A Workshop Report. http://
serc.carleton.edu/research_on_learning/workshop02

Tversky, B., Bauer-Morrisson, J., Betrancourt, M., 2002, Animation: can it Facilitate. International Journal of Human-Computer Studies. 57(4), 247-262.

Uttal, David, 2002, Understanding Geoscience Images: Insights from Cognitive Science, Geological Society of America Abstracts with Programs Paper No. 167-3
Abstract: http://gsa.confex.com/gsa/2002AM/finalprogram/abstract_43773.htm
Presentation: http://serc.carleton.edu/research_education/talks.html