Visualization in Science Education

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Visualization has been part of science since the first diagrams, charts, or graphs were sketched at the very beginning of what we now recognize as scientific thinking over 2,000 years ago. We have long known that we can communicate an idea with a sketch that would take a great deal of time to communicate in other ways, and we've also learned that the act of creating such a sketch can effectively expose errors or incomplete knowledge and clarify understanding. So visualization, or visual thinking, is an old friend of the sciences.

This old friend has taken on new meaning with the recent development of high-quality graphical computing resources. In 1987, the groundbreaking NSF-sponsored report, Visualization in Scientific Computing, raised the consciousness of the sciences to the potential of using computer-based visualization to lever the understanding of science. This report also led NSF to begin funding visualization research in the early 1990s. Now that the computing resources for visualization are available on low-cost desktop computers and software tools are becoming affordable, we are able to give students the same high-quality visualization capabilities that were formerly available only in expensive research labs.

The first four chapters in this section describe CCLI-funded work that addresses this task with current tools. LeGates discusses the role spatial analysis and data visualization play in introducing social science students to research methods. He argues that the exploratory data analysis given by visualization and geographic information systems (GIS) teach students to formulate and refine hypotheses, and he advocates teaching these at the beginning of students' studies rather than later. Hall and Walker describe the ways they use GIS in teaching earth science. They teach students with GIS rather than teaching students about GIS, supported by ever-simpler tools and carefully simplified data. Moving this topic into the lower-division courses enhances the learning experience for students in many fields. Reynolds et al. present spatial visualization as an essential component of geology courses and give a number of examples of different tools he uses in building student visualization skills. While many of these involve students using prepared visualizations, others give students the ability to interact with or control the visualizations they see. Finally, Blanchard takes the concept of creating single-image visualizations as a given, using tools such as Mathematica®, and he shows how to create computer animations from sequences of these images. The tools are straightforward, but the effects are dramatic and illustrate the dynamic nature of the concepts being presented.

In a slightly different direction, the next two chapters look at projects that represent a direction for the future of visualization in science education. Wattenberg proposes an ambitious program to develop a scientific culture of modeling and simulation for education. This modeling should have both hands-on and digital parts, including physical devices for modeling where possible and extending the modeling experience with computing tools. Students advance from using prepared models to modifying and then developing models as their skills and experience grow, reinforcing the centrality of modeling to the sciences. Frankel shares the idea of having students create visualizations as a key part of their science education, but her focus is on the learning that is represented by her students understanding concepts well enough to communicate them effectively through visualizations. She discusses both tools for visualizations and the concept of learning to create visual metaphors for science.

In the near future, we expect to see computer-based visualization work becoming a common part of science education, and this is already starting as early as the elementary grades. This work will become increasingly interactive and will encourage students to participate in exploring ideas, not just seeing them presented. The ideas of students building their own models and images in the Wattenberg and Frankel chapters are particularly exciting. Learning is an active process that requires learners to create knowledge themselves. Students can create knowledge effectively by creating their own models of scientific principles and processes and then visualizing these models to test their accuracy. This opens the door to the idea of "Visualizing to Learn," an approach to science teaching that supports active learning by students who are engaged with and communicating ideas. But visualization is still a new activity and is still more a part of research than of learning, so there is a need for research and evidence to understand how to make visualization the effective educational tool we believe it can be.