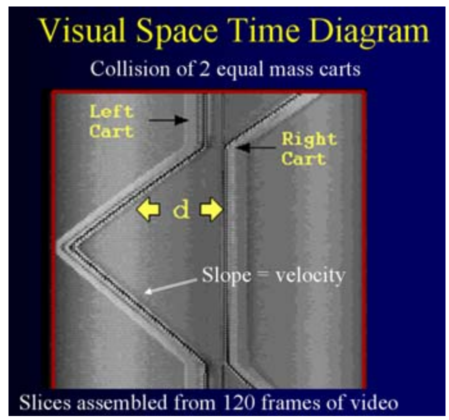
Multiple Representations, Scientific Visualization and Student Learning of Science

S. Raj Chaudhury
BEST Lab/Physics
Norfolk State University, Norfolk, VA 23504

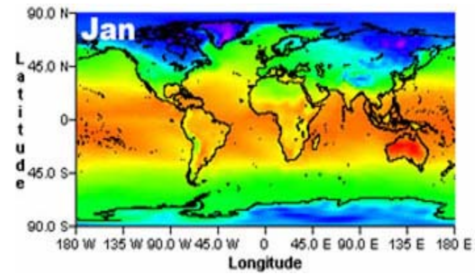
As a scientist trained in physics, who since graduate school has worked almost exclusively in problems of education, I have been really enjoying learning about visualization, cognitive processes in young adults and also about global climate change. In this essay, I would like to establish the background for my current research interests, share some of my influences and expand upon the title and its significance for college science instruction.

My interest in the use of visual media for learning science started with my involvement in a project looking at the uses of digital video for physics instruction. The idea was to treat digital video as a data stream and not just a VCR on the computer. Thus, one should be able to extract useful physical information from the digital video (e.g. the time rate of change of positions of certain objects within the frame) and in other ways manipulate the video information in space and time (Chaudhury & Zollman, 1994). On the right is an example of what we called a 'Visual Space Time Diagram' - because it compressed the physical information from several seconds of video (several dozen frames) into a single still image that still retained the essence of the physical phenomenon that had been captured on video originally (two carts on tracks colliding elastically in a straight line). Some manipulation of QuickTime video in space and time is now being done with software such as DIVER (Pea et. al., 2003)



While video presents one kind of challenge of a large data set – earth remote sensing data presents a whole other set of issues when it comes to usability in the classroom with the appropriate tools and curricula. Two dimensional line plots (whose application has been widely studied in the physics education research community) are no longer enough to represent the richness of data that describes aspects of the Earth's environment. For the past several years, I have been working with tools and data from NASA's Earth Observing System to meet the needs of two distinct audiences – undergraduates in a summer research program on Earth System Science and K-12 teachers. In our case, both groups were relative novices to the discipline and unfamiliar with the data products available (Chaudhury & Rodriguez, 2003; Chaudhury et.al., 1997). In rapid succession we escalated the type of data we handled from 3-D (e.g. false color images of ozone laid over a two dimensional world map), to 4-D (e.g. animation of a time series of false color images to show changes in ozone concentration over a period of several months) to Virtual Reality (e.g. the same ozone data rendered in an immersive environment where one could change perspectives and viewpoints).

As part of capacity building at NSU, we engaged scientists, undergraduates, graduate students (Education) and K-12 teachers in these endeavors. The early lesson we learned was that each audience, each learning objective demanded its own tool and that NASA data (though there was plenty of it) was rarely in the form that was useable for meaningful interactive visualizations. WorldWatcher (Edelson, 2004) was one software tool that found applicability across multiple domains of users within the sphere of education – and visualizations created with it have been used on a number of occasions in my courses. This figure shows a WorldWatcher representation of global surface temperature (in January) is shown here. For undergraduate research purposes, however, the tools of scientists (IDL from RSI Inc.) became more critical simply because they could be programmed to accept data input from a variety of sources. From a purely visual perspective, IDL allows one to generate graphics and animations similar in many ways to what WorldWatcher does, though that is where the similarity ends. Our preliminary research in college science classes with visualizations such as the one shown here indicate that non-science major college students can be trained quite readily in the basic interpretation of such images. We have adapted instructional methodologies from the Physics Education Research literature and designed paper and pencil assessments for the use of scientific visualization tools and data in a traditional lecture setting (Chaudhury et. al., 2002)



As many others have mentioned in their essays – graphical visualizations are only part of the cognitive load that learners have to bear when dealing with topics in science. It is not easy to find ways to link natural phenomena to their graphical representation without introducing artifacts that could distract the student from the true concept to be learned. The stated goal of many scientific visualization projects is 'enhanced student learning' of topics in some particular domain – whether it be geology, meteorology, anatomy or chemistry. However – an issue that often gets overlooked in many of these discussions is that of the 'multiple representations' of phenomena that most scientists master along the way and that often brings clarity to their own mental models of the concepts. Within the context of a college science course, scientific representations of phenomena can be verbal (descriptions in the textbook), aural (professor's lecture), numerical (data collected in lab), symbolic/mathematical (equations to be solved), diagrammatic (flowcharts/schematics) and finally graphical (charts/false-color plots etc.). Some of the issues for students are : when to use which representation? how to move between representations? are all representations equal in scientific merit? Challenging questions indeed! Within the realm of physics education, Van Heuvelen and others have paid special attention to student needs in this area and devised curricular strategies to help them make the representational transitions – especially at the calculus-based study of Newtonian mechanics. Within the overall sphere of geosciences education, I am not sure whether or not this issue has been addressed.

This year, as part of my work with the Carnegie Academy for the Scholarship of Teaching and Learning (CASTL), I am investigating how students in an introductory physical science course deal with issues of multiple representations – and especially focusing on whether or not they can be steered towards making maximum use of the visualizations provided in the textbook to overcome weakness in reading level (verbal representations) and math (symbolic and numerical representations). For example: my instruction on objects moving under the influence of gravity (in Week 3) and on the Solar System (Week 8) comprised *only* of a detailed discussion of certain relevant diagrams in the textbook. Some of the assessment data were encouraging and some were surprising – I shall share my preliminary results in my poster.

In terms of this workshop, I would like to learn about what others are doing especially at the introductory college level and form collaborations with people who could bring to bear their expertise in areas such as cognitive science and psychology – something I sorely lack!

References:

S. Raj Chaudhury & Dean Zollman, “Image Processing Enhances the Value of Digital Video in Physics Instruction”, Computers in Physics 8, 518-523, (1994)

S. Raj Chaudhury, W. J. Rodriguez, B. J. Cooper-Pabis, K. Lee, "Using Ranking Tasks to Introduce Scientific Visualization in the Lecture", presentation at the AAPT National Meeting, Philadelphia, 2002

S. Raj Chaudhury & W. J. Rodriguez, “Scientific Visualization & Modeling for Earth Systems Science Education,” Proceedings of 90th Indian Science Congress, Part IV, Bangalore, India, 2003

S. Raj Chaudhury, G. Golembiewski, S. M. Black, W. J. Rodriguez, T. Marks, “DAACeSS - A multimedia CD-ROM for Earth System Science”, Proceedings of the Seventh NASA MU-SPIN User’s Conference, New York, 1997

D. C. Edelson et. al., WorldWatcher Project, http://worldwatcher.nwu.edu/, Northwestern University, last accessed Feb 20, 2004

Roy Pea et. al., DIVER – Digital Interactive Video Exploration and Reflection, Stanford University, http://diver.stanford.edu/, last accessed Feb. 20, 2004