Geovisualizations for pre-collegiate science education

(Revised)

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My academic training lies within the realm of educational technology research and instructional design. As a collaborator, I'm often paired with scientists or science educators, with a vision for research or product development but generally uninterested or unable to implement ideas due to technical or educational research restrictions. In this capacity, I design, implement, and evaluate educational products and courses. Visualization products and tools (digital mapping, animations, and imagery) occupy a substantial position in my research and development efforts. In addition, I'm generally able to utilize these resources in the teacher education courses in which I instruct.

The context for visualization

My initial interests in visualizations grew from early involvement with an online science education community, The Kansas Collaborative Research Network (KanCRN – http://pathfinderscience.net), a 1997 Department of Education Technology Innovation Challenge Grant. KanCRN stressed project based learning through "meaningful, authentic science" for middle and high school students, using the Internet to establish discourse with a mentor/advisor and other participating students. A substantial effort of the grant involved student participation in the entire scientific research process, not simply one *decontextualized* piece of a scientific research process (for example, data collection). Student work at KanCRN was centered on one of several different project areas, some of which included: Global Warming, Tardigrades as bioindicators, Stream Monitoring, Lichens and Sulphur Dioxide, Particulate Monitoring and Phenology.

As students began study in a project, they would initially follow a well-defined framework for conducting research. Initially, student involvement was designed to *create a context*, providing basic subject-specific information and research skills necessary for promoting future, personally-meaning research. While students working in this initial stage, appropriately called *Creating the Context*, did not engage in scientific research, they were expected to gain the requisite facilities and expertise for doing research (working with a research question, collecting pertinent information, collecting relevant data, analyzing data, drawing conclusions, identifying potential social action, etc.).

Students who completed *Creating the Context* inevitably asked more questions, questions that grew from their new experiences and knowledge. These young researchers were directed into a new phase of study, *Guided Research*, were students were allowed to design and implement a study based on their own questions related to the project. Allow stringent controls were in place, via Internet technologies, students had great liberty to pursue questions of personal interest. Following the same structure of scientific inquiry set forth in *Creating the Context*, students would ask questions, collect and analyze data, attempt to form conclusions, and most importantly devise further research questions.

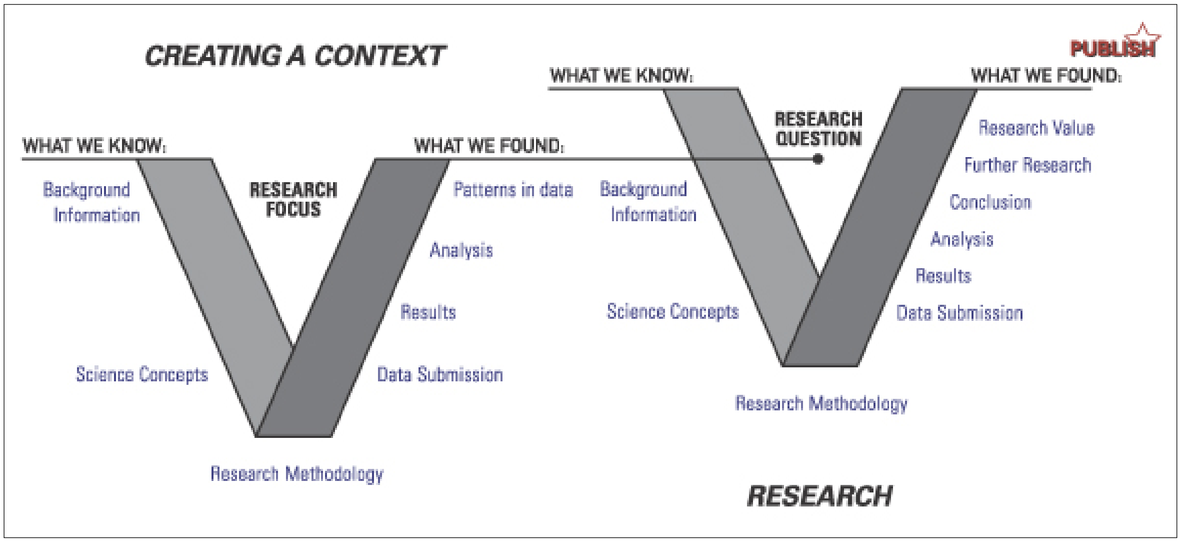

Figure 1: The KanCRN Double Vee-diagram, © PathFinder Science, LLC

Throughout the development and implementation of KanCRN, it was apparent that some form of data visualization technology would be critical for successful data analysis. Many projects, particularly the *Creating the Context* side of many projects, had hundreds and even thousands of student-submitted data points. In many cases, the data were geographically-relevant making spreadsheet only partially useful and the choice of digital maps (or Geographic Information Systems) one apparent approach to providing students with a visual account of their data.

As a case in point, 120 middle school science students engaged in the KanCRN Lichen and Sulphur Dioxide project, an effort to measure relative air quality using tree lichen as a bioindicator of air quality. This research study used a non-equivalent quasi-experimental research design, wherein two versions of a two-week Project Based Learning unit were developed, implemented, and assessed. Students used a collaborative GIS or paper maps to support data analysis activities in this eighth grade Earth science unit. Attitude and self-efficacy in science and technology as well as student achievement in science process skills were measured. The study found significant improvement in attitudes toward technology, self-efficacy toward science, and modest, yet significant, improvements for geographic data analysis for students who used GIS (Baker & White, 2003; Smith & Baker, 2003).

Extending Scientific Inquiry through Collaborative GIS (ESIC-GIS)
Getting a professional-grade GIS to work for schools requires a substantial commitment of time and resources on the part of schools, teachers, and students. ESIC-GIS (http://gis.kuscied.org) is a teacher enhancement grant awarded to the University of Kansas to train in-service K-12 science educators in the use and integration of this data visualization tool. The program focuses on the development of curriculum in a combined online and onsite course along a developmental pathway to teaching *with* GIS and

remote-sensing technologies in the science classroom (see Baker, 2000). The program has several ongoing, embedded research agendas, including investigating student learning from cartographic animation, teacher content acquisition and GIS skills implementation, and teacher training motivation. ESIC-GIS is set to conclude during the fall of 2004.

As part of a research efforts associated with ESIC-GIS, a nationwide collection of data regarding students' learning and performance in understanding graphically rendered GIS data on a number of topics. One example of such GIS data concerns tornado reports across the U.S. over the last several decades. The locations of such reports are superimposed across a map of the continental U.S., and for each report, a dot is generated and placed on the appropriate point on the map. Several maps are presented, each representing a different month of the year. With this display, it is the student's task to draw content information and conclusions about the relative frequency of tornado activity as a function of geography (i.e., region of the U.S.) and time (month of the year). The material has been presented in one of three ways: (a) *static*, in which a list of links is presented, each representing a particular month, and where the student is free to click through each at his/her own pace, and in any particular order; (b) *animated with controls*, in which each monthly display is presented in a sequential fashion, producing apparent motion in which the density of tornado activity moves regionally month-by-month, but where the student has "buttons" that allow for the stopping, pausing, playing, reversing and fast-forward/fast-reverse of the sequential program; and (c) *animated*, in which each month-by-month display is presented in a sequential fashion, but without the buttons which allow students to control the flow of the map sequences. After viewing these exemplars for some amount of time, students are then asked rigorous content questions about the display in order to determine how much they have learned, and are asked to generate inferences and conclusions about the nature of the phenomenon represented as an index of the quality of inquiry the display has engendered.

In the course of conducting research on students' performance under different presentation systems, they observed a number of findings regarding the conditions under which students learn best. One particular finding contradicts the intuitive sense that the presentation of information in animated, dynamic displays should enhance or facilitate learning. Indeed, it was observed that students learned GIS-based information dramatically better under conditions where information is presented in a *static* format. The superiority of static displays yields performance that is significantly better, relative to that seen for animated displays (with or without controls). As counterintuitive as this finding appears, it seems to support conclusions highlighted in a meta-analysis on the effects of the form of visual presentation and display on learning published by Tversky, Morrison, & Bettrancourt (2002), in which animation consistently produces either null or deleterious effects on learning from graphical displays. We believe these results offer immediate implications to the ESIC-GIS program, directing future curriculum development and visualization tool selection. Currently, efforts are underway to replicate, expand, and publish this study.

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