Bringing Advanced Science Inquiry Tools in for a Soft Landing: Report of a Five Year Study

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Abstract: Scientific visualization tools have shown tremendous promise in drawing today's increasingly visual learners into in-depth inquiries in mathematics and science. But there is little data that describes how successful teachers are in using these tools with their students in the chronically under supported technological settings of K-12 education. This paper uses a stages of adoption model to describe teacher progress in utilizing four visualization tools to facilitate project-based scientific inquiry. Summary data are presented from forty-five participants in this longitudinal study based on follow-up questionnaires and interviews that describe how some teachers have begun to integrate these relatively advanced scientific visualization tools into their teaching practice.

Scientific visualization tools offer a rich use of the more powerful computers that are becoming more and more plentiful in schools today. These are a set of inquiry-based tools, many of which were originally designed to help scientists understand and explore different datasets or physical phenomenon. Visualization tools have shown great promise in drawing today's increasingly visual learners into in-depth study of scientific and mathematical topics (Baker & Case 2000; Greenberg et al. 1993; Gordin & Pea 1995; Jonassen 2000; Thomas, Johnson, and Stevenson, 1996; Malinowski, Klevickis & Kolvoord, 2001).

Both the promise and the relatively advanced nature of this software leads to the question of how to get more teachers involved in using visualization tools in their classrooms. Many projects offer extended training for teachers in one of these more advanced tools, but extended training in the first exposure to a new tool is often too much, too soon. Project Visualization in Science and Mathematics (VISM) is a recently completed NSF-funded project intended to focus more broadly on the techniques of visualization and not so much on particular tools. The approach taken in Project VISM was to provide participants with a relatively brief look at several different tools versus an extended exploration of one tool.

The goal of Project VISM was to develop a cadre of middle school and high school, teachers cross-trained in several different visualization tools who would serve to seed the development of other teachers in the use of these same tools. The teachers learned four specific data visualization tools, taught by instructors from both high school and university faculty who use these tools with their students. The tools were:

- Image processing with NIH Image, Scion Image, or Image J software
- Geographic Information Systems (GIS) with ArcView GIS software
- Molecular visualization with RASMOL and Chemscape Chime software
- Systems modeling simulations with STELLA software

Project VISM conducted five different summer workshops in the techniques and application of data visualization for math and science teachers at James Madison University’s Center for Interdisciplinary Science and Technology (CISAT) in Harrisonburg, Virginia. These workshops were conducted over three summers, with one four-week workshop in the summer of 2000 and two three-week workshops in each of the summers of 2001 and 2002. A total of 118 participants took part. In the summers of 2003 and 2004 a three-day follow-on workshop was offered for interested participants. The first of these follow-on workshops took place at James Madison University in Virginia and the second took place at Pacific University in Oregon. At these follow-on workshops participants had a chance to refresh and further develop their skills in using these more advanced data visualization tools. The participants were also formally asked to describe the ways they were using the tools with their students, the workshops they were conducting for other teachers, and the impact that the project had on their professional lives.

Landing visualization tools in teacher's professional practice

The four tools taught in Project VISM are relatively advanced tools for K-12 educators to use with their students. Drawn from the practicing scientific community, these tools are used in settings with greater technical support than what is generally available in K-12 classrooms. A key question of the project was to what extent would teachers be able to use the tools taught in Project VISM in their own classroom. This could be described this as "landing" a tool in the teachers' professional practice to suggest the difficulty and skill required to accomplish this as being analogous to landing an airplane.

The Apple Classroom of Tomorrow (ACOT) model describes four stages teachers progress through in moving new technological tools into their practice: entry, adoption, adaptation, and innovation (Sandholtz et al. 1997). In collaboration with the instructors in the project, the VISM matrix (Appendix A) was developed for this project based on the ACOT model. This matrix describes each of these four ACOT stages in specific terms for each of the four tools that were taught in the VISM workshop. These descriptions were refined and revised based on feedback from the instructors following the first and second summers of the project. The matrix was developed to assist in describing the way that teachers use the tools with students in their classrooms and how that use evolves over time.

To better understand how the participants were using the tools, we began by conducting a few in-depth interviews as of teachers a year or two following their participation in the project (Charles & Kolvoord 2001). We eventually completed ten interviews and wrote very brief case studies of those participants' experiences (Charles & Kolvoord 2004). In the past two summers we have collected data from a larger group using a follow-up questionnaire that was derived from the interview protocols. We have administered that questionnaire to a total of thirty of the participants as they have taken part in the follow-on workshops.

Analysis of this data and collection of further data from more of the participants is ongoing. The data are self-report. There are limitations on the usefulness of the current data since it was collected from those who attended the follow-on workshops. This is a group that would logically be more interested in using the tools since they came back for an additional weekend workshop. Still this preliminary data gives some insight into the actual use of the tools. Below preliminary data is presented concerning three questions:

- How many of our participants rate themselves at the adopt, adapt, or innovate level with the tools?
- How are the participants' abilities in using these tools holding up over time?
- What has been our participants greatest obstacle in using these tools with your students?

Table 1 summarizes the teacher's response to the question "How did you use the tools with your own students." The possible responses were:

- used an activity from the workshop ("adopt" level from the VISM matrix);
- used several activities from the workshop ("adopt" level from the VISM matrix);
- adapted an activity from the workshop ("adapt" level from the VISM matrix);
- created my own activity ("innovate" level from the VISM matrix).

Different teachers may have selected more than one response for a given tool, and it was not expected that all participants would use all four tools.

	Adopt		*Adapt*	*Innovate*	*Totals*	*%*
How did you use the tools with your own students?	used an activity	used several activities	modified an activity	create own activity		
Image processing (Image J/ NIH Image/Scion Image)	7	17	14	15	*53*	***37.9%***
Geospatial analysis (ArcView)	9	5	8	16	*38*	***27.1%***
Simulation (STELLA)	7	5	4	10	*26*	***18.6%***
Molecular visualization (RASMOL/Chemscape Chime)	11	3	3	6	*23*	***16.4%***
totals	*34*	*30*	*29*	*47*	*140*	
%	***24.3%***	***21.4%***	***20.7%***	***33.6%***		

Table 1: Participant ratings for how they used the VISM tools with their students

Based on their own self-rating, about 45% of the responses were at the adopt level, 20% of the responses were at the adapt level, and about 33% of the responses were at the innovate level. There is certainly evidence that teachers are using the tools with their students, with nearly a third of the uses at the highest (innovate) level.

According to the responses, the image processing tool is being utilized by about 38% of the total projects. This is a not too surprising because many of the participants came to the workshop with prior experience in at least learning to use image processing tools. The geospatial analysis tool is the next most often used tool, with 27% of the responses. Of the four tools in Project VISM ArcView is the one with the greatest use by the general K-12 teaching community. The simulation software and the molecular visualization software have about the same number of the responses at about 19% and 16%. This is actually a higher level of use than expected, and is higher than the earlier interview data indicated.

Table 2 summarizes the participants' responses as to whether they had become more or less competent in using the tools learned in the workshop during the past year. About 25% of the responses were that they were less competent (a 1 or 2 on the 5 point scale). About 25% of the responses were neutral (a 3 on the 5 point scale). Nearly 50% of the responses were that they were more competent in using the tools (a 4 or 5 on the 5 point scale).

Were there any changes in your abilities with each of the tools after this year?

	less competent 1	2	3	4	More competent 5	***total***
ArcView GIS	*3*	*5*	*7*	*6*	*23*	***44***
Image J	*4*	*1*	*12*	*13*	*14*	***44***
STELLA	*9*	*7*	*12*	*8*	*7*	***43***
RASMOL/Chemscape Chime	*8*	*7*	*15*	*7*	*5*	***42***
	24	***20***	***46***	***34***	***49***	***173***
%	***13.9%***	***11.6%***	***26.6%***	***19.7%***	***28.3%***	

Table 2: Participants' ratings of any changes in their abilities to use the Project VISM tools in the year(s) following the workshop

Project VISM included very limited follow-up during the year, so it is surprising to note how many of the participants developed greater competency using the tools. Previous interviews suggest that many of the teachers extend their knowledge of these tools by using them with their students. In addition a number of the participants report pursuing additional training or securing additional support materials relating to the tools from sources other than Project VISM that helped them extend their knowledge and use of the tools.

Table 3 summarizes the participants' responses as to what they perceived to be the most serious obstacles to using the Project VISM tools in their classroom. The mean response is from 3.4 to 2.3, which is not a very broad range. Still a few observations can be made from this preliminary data.

	not an obstacle ***1***	***2***	***3***	*serious obstacle* ***4***	***5***	**Mean**
Lack of space in a crowded curriculum to do projects that use these tools	*5*	*5*	*11*	*13*	*9*	**3.4**
Lack of adequate teacher preparation time to prepare activities	*9*	*6*	*10*	*13*	*6*	**3.0**
Lack of teacher knowledge of these software tools	*6*	*9*	*14*	*9*	*6*	**3.0**
Lack of well-designed curriculum-based materials using these tools	*10*	*5*	*14*	*11*	*2*	**2.8**
Relating the use of these tools to increasing student achievement scores	*9*	*11*	*14*	*8*	*2*	**2.6**
Lack of adequate hardware/software	*12*	*11*	*8*	*7*	*5*	**2.6**
Student difficulty learning the tools	*8*	*19*	*11*	*3*	*1*	**2.3**
Incompatibility of these tools with district's stated educational objectives	*16*	*13*	*4*	*6*	*4*	**2.3**

Table 3: Participants' ratings of the obstacles they face in implementing these tools

The participants do not generally think their students will have a great deal of difficulty using the tools and they appear to generally have adequate hardware/software; what they perceive as the difficulties are related instead to a lack of time to do these inquiry-based projects with their students inside an increasingly crowded curriculum, a lack of time to prepare activities, and a lack of time to further develop their own knowledge of the tools. It is interesting to note that the teachers were *more* concerned about their own lack of knowledge of these tools *following* the workshop than they were at the beginning of Project VISM. Perhaps this is because after they have learned more about the tool and tried to use it with their students for a year or two they realize how much more there is still to know about using these visualization tools drawn from the scientific community.

Project VISM: The value of high quality workshops in removed settings for K-12 educators and the impact on classroom use

In the past five years the preliminary findings of Project VISM have been disseminated at a number of national and local conferences (Charles & Kolvoord, 2001, 2003, 2004). In following up with the teachers in the project and reflecting on how teachers are able to move scientific visualization tools into their teaching practice, several different issues are summarized below.

Project VISM developed some refinements to the ACOT model that are pertinent to the kinds of more advanced tools teachers were asked to use with their students. The current ACOT model bases each of the stages on a given level of competency with the technological tool, and describes their development in using that tool with their students. But in working with scientific visualization tools with teachers, this competency appears to have three component parts. Those three parts are:

- Competency with the software tool
- Competency with the scientific data that the tool uses
- Competency with the pedagogical content knowledge needed to teach curricular content using the tool

These three components help determine a teacher's ability to move forward into the next stage of development in using a given tool. In particular, competency with the scientific data can be an initial challenge. In the case of learning ArcView GIS, many teachers can learn to use the tool with a sample data set and generate meaningful maps for their students. The challenge comes in trying to bring a different data set into the program. With these tools, this is not as simple as opening a word processing document.

Project VISM also sheds some light into the nature of effective professional development experiences for teachers that use advanced technological tools. In many of the discussions of professional development there is a good deal of discussion about "building capacity" in the system and "ramping up technological change." These sound like production metaphors, which may be helpful in highlighting the importance of creating "sustainable" professional development efforts. But they may also obscure the fundamentally constructivist nature of teacher learning. It is striking that over half of the Project VISM participants report actively pursuing further professional development in the use of these tools even though very little of this came from the project. This suggests that teachers actively pursue a program of professional development that is their own particular construction even if it is not a part of a recognized district or academic program. This is often overlooked in discussion of professional development, and it argues for using tools that have broader user communities with resources that can be tapped well beyond a given project.

The barriers that teachers face have some common features even though the teachers in this nationwide project work in many different states and in very different schools. Especially in implementing advanced tools, there is a need to have blocks of planning time to develop skill with the tool and to be able to think through the curricular uses of the tool with students. Absent this time, teachers will struggle to do the creative work that leads to the innovate stage. Nevertheless, a third of the teachers report reaching the innovate stage despite these barriers. Just how much additional time it would take to enable more teachers to reach that stage is a question worthy of further inquiry.

Successfully disseminating the work of more innovative teachers to other teachers in a form that they could readily use in their classroom is an ongoing challenge of this kind of work. By its nature, innovative work that is grounded in local issues is idiosyncratic and difficult to transport to other areas. Abstracting the lessons to more general, less local issues seems to somehow denature them. This is an unresolved, but very important problem in trying to take advantage of the work of creative teachers and share it with their colleagues across the country. Teachers' effective use of these tools seems to be profoundly local, but dissemination must be more general.

Finally, the success of Project VISM raises some questions about the current prevailing wisdom regarding teacher professional development, which advocates local site-based, curriculum-specific professional development efforts with significant on-site follow-up. Project VISM was a nationwide university-based program with materials that had only general curriculum connections and with no significant on-site follow-up. The former approach certainly has merit, though serious questions remain about the long-term sustainability and scalability of many of the projects that feature such an approach. But the data from this project argues for the continued need for excellent national-level university-based programs where teachers learn a great deal personally and are charged with a great deal of responsibility for taking this new learning and applying it to their own practice. The emerging consensus that effective professional development efforts for teacher should resemble corporate-style training sessions may not give sufficient credit to the intrinsic motivation that drives successful educators to conduct what is in effect their own program of professional development, one that is unique to each professional. Further discussions with the teachers in this project may better describe the fundamentally constructivist nature of teacher learning.

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APPENDIX A

VISM Matrix