Using Visualization to Make Connections Between Math and Science in High School Classrooms

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Abstract: Today's students are receiving "superficial" knowledge of math and science concepts. According to a report from the National Commission on Mathematics and Science Teaching for the 21st century, in science, students are not mastering the "big concepts," while in mathematics, they are given little information about "how" and "why." To address these concerns, connections need to be made between mathematics and science. Visualization combined with Problem Based Learning (PBL) is one teaching strategy that can be used to address these issues. This paper reviews the findings of a study conducted at two mid-western high schools that used visualization in math/science classrooms. The results revealed that students made meaningful connections between math and science data, connections between math and science language, and connections between math, science and daily life experience.

According to the report from The National Commission on Mathematics and Science Teaching for the 21st Century (2000), entitled *Before It's Too late,* U.S. students are receiving only a superficial knowledge in today's classrooms. The report states, "In an age now driven by the relentless necessity of scientific and technological advance, the preparation our students receive in mathematics and science is, in a word, unacceptable. Despite our good intentions, their learning is too often superficial. Students' grasp of science as a process of discovery, and of mathematics as the language of scientific reasoning is often formulaic, fragile, or absent altogether" (p. 10). The report notes that the problem with current science education is that students are not required to master "big concepts that make science so powerful and fascinating" (The National Commission on Mathematics and Science Teaching for the 21st Century 2000). In mathematics, the content is limited to questions that answer "What" and get little content that addresses "How" and "Why should I care." These two issues could be addressed by making connections in the classroom between science and mathematics. These two subjects and the daily world are linked. Scientists generate data and use mathematics as a tool for data analysis. Yet, in our education system, students see these two subjects as separate and distinct because we have chosen to teach them separately giving students a dichotomous view of science and mathematics

One teaching strategy that could be used to make connections between science and mathematics is visualization. Combined with Problem-Based Learning, visualization uses classroom technology to help the learners create a visual picture of concepts and make connections between mathematics and science through discovery learning experiences.

According to the 1999 report, *How People Learn* (Bransford, Brown, & Cocking 1999), from the National Research Council, technology can be used to help supply five key conditions for learning. These conditions are central to the success of visualization. They include real-world contexts for learning; connections to outside experts; visualization and analysis tools; scaffolds for problem solving; and opportunities for feedback, reflection and revision.

First, technology can support real world context for learning by using simulations, which can form the basis for Project Based Learning. Project Based Learning uses in class projects that are used to cover course content and fulfill certain course objectives. Students have the opportunity to work on the project as teams and report their results to the entire class. One way to do this is through the use of simulation. Simulation exposes students to real-world problems to which they must find solutions. They are looking for answers that are "situation specific" rather than the "right answer" from a textbook (Teaching and Learning 2001).

Second, technology can connect students with outside experts. Through the Internet, students can have access to experts in practically any field all over the globe. They can send e-mail to them and even "chat" with them online. In one of my own classes, the students became very excited when they were able to have their questions answered during a "chat" session with a well-known expert in education. Students can also download documents that are not available in the library, and they can keep up with the latest research.

Third, technology can provide visualization and analysis tools (Harnisch 2000). Rather than talking about concepts, teachers can use technology to visualize them. For example, schools that do not have microscopes can use advanced imaging technology to look at the parts of a flower rather then relying on textbook photos or drawings. Also, 3-D imaging allows chemistry students to construct a three-dimensional model of an atom and animate it so they can see it from all sides. In mathematics, graphing calculators can visually show students relationships between variables. Concept mapping using "Inspiration" software can help students visualize processes and relationships.

Fourth, technology can provide scaffolds for problem solving (Harnisch and Sato, 1990). In today's rapidly changing world students need to learn much more than the knowledge written in a textbook. They need to be able to examine complex situations and define solvable problems within them. They need to work with multiple sources and media, not just the single textbook. They need to become active learners, and to collaborate and understand the perspectives of others. What we are talking about is the ways in which students today need to learn how to learn; that is, they need to learn how to:

- Ask: find problems
- Investigate: multiple sources/media
- Create: engage actively in learning
- Discuss: collaborate; diverse views
- Reflect: learn how to learn

This shift to an inquiry-based mode of teaching and learning is now widely recognized (Bruce & Davidson 1996; Minstrell & Van Zee 2000; Shavelson & Towne 2002; Wells 2001). The National Science Foundation has asked for "research-validated models (i.e., extended inquiry, problems solving)." The Carnegie Foundation's Boyer Commission on Educating Undergraduates in the Research University (1998) has set its number one priority to make research-based learning the standard. The American Association for the Advancement of Science, in its Project 2061, has as its number one goal to have "science literacy for all high school graduates," by which they mean to develop the broad, critical perspective and habits of mind that develop through scientific inquiry.

Fifth, technology can provide collaboration between students, teachers, and outside experts that help students to solve problems. Through email, discussion boards, and web pages, students have access to educators, and to experts who can help them to think through problems. Also, technology can provide students with problem-solving experiences by developing "Inquiry Units." This is available to both teachers and students through a web site at the University of Illinois at Urbana-Champaign at http://inquiry.uiuc.edu/. The "Inquiry Page" is more than a web site. It's a dynamic virtual community where inquiry-based education can be discussed, resources and experiences shared, and innovative approaches explored in a collaborative environment. One example is "Web Quests" which will help them to develop problem solving skills. Based on John Dewey's philosophy that education begins with the curiosity of the learner, we use a spiral path of inquiry: asking questions, investigating solutions, creating new knowledge as we gather information, discussing our discoveries and experiences, and reflecting on our new-found knowledge. We invite you to visit the inquiry page. There are lessons on life that can be downloaded and adapted for use in your classroom. Also, you can place inquiry units on the page and access them from anywhere in the world. Your students can also develop units as part of a lesson and put them on the page to share with others. By doing this, you will become part of a world-video learning community.

The Study

The Visualization teaching/learning strategy was tested in two mathematics and science classrooms in a suburban high school during the 2000-2001 school year. In each school a math/science cohort of 25 learners was formed and a teaching team of math/science teachers. The learners consisted of Honors students taking Algebra II with Trigonometry /Honors Chemistry at one school, and "G" learners having a combination of Algebra II/Physics at the other school. The learners took math and science together as a group rather than changing classes. In addition, the teachers had the opportunity to observe each other's classes. The Project Based Learning (PBL) Coordinator, who was a teacher that specialized in PBL and was selected for the project, trained each teacher in PBL. In addition, the Associate Superintendent of Schools, and the Assistant Principal of each of the schools was kept informed of the progress of the project. This collaboration helped to form a foundation for a culture of learning in math and science at each school.

During the project, students had access to classroom technology including computers, software, web access, graphing calculators, and science laboratory equipment. The Honors class also had the opportunity to upload projects to a secure website for review.

The data for the project consisted of survey instruments, images of projects, field observations, student and teacher reflections, teacher portfolios, interviews with teachers and school administrators, and student focus group interviews. Some of this data was collected electronically using a secure website.

Findings

The use of visualization and the grouping of students into math/science cohorts and teachers into math/science teaching teams helped students make connections between math and science. Through visualization, which also facilitated collaborative learning, students and teachers built a math/science learning community that was formed through their shared classroom experiences. This is illustrated in Figure 1.

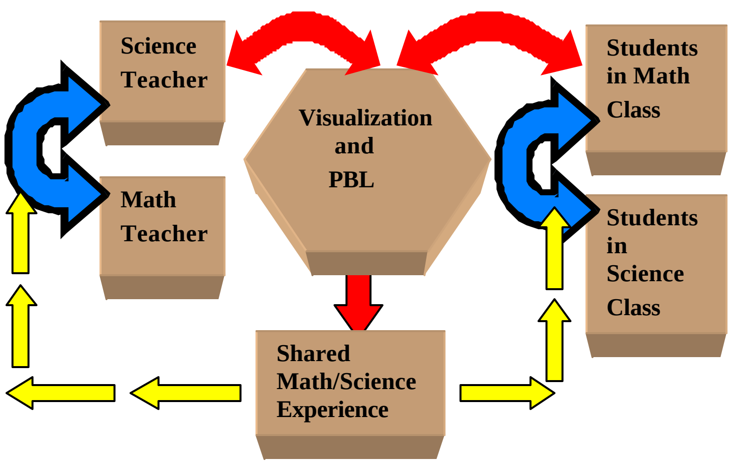

Figure 1: Math/Science Collaborative Learning Community

Visualization helped students and teachers make connections between math and science. There were three types of connections that were made. First, there was a "data" connection, second, there was a "language" connection," and finally, there was a "life" connection.

Data Connection

Students had the opportunity to make connections between math and science by using mathematical formulas and concepts to analyze and draw conclusions from data they had generated in a science class. For example, the students in one cohort spent the day in research teams throwing softballs at different angles and measured the angles and distance of each throw. The students then used vector concepts and formulas to determine which was the best angle to throw the ball to achieve the greatest distance. In their reflections, students remarked about the connections they saw between mathematics and science. A student wrote, "We created connections from Algebra 2 to chemistry in different ways. For example, when we were learning about log in Algebra 2, at the same time we were learning to determine the pH of different substances. We used 'log' in the equation."

Language Connection

Second, visualization helped students and teachers begin to form a common math/science language. One of the department heads associated with the project noted, "completely integrating a Math and Science course may not be feasible, but speaking a common language in all Math and Science classes would be very powerful." The advantage of a common language to the student is that now students began to see a common set of terms for a concept rather than two sets, one in math and one in science. Teachers also see this as a big advantage. One math teacher said that a common terminology would help the students make connections between the two disciplines because, although math and science have common concepts, they use different terms to describe them. One of the administrators also added that a common language would also serve to make the curriculum more cohesive.

Life Connection

Finally, the students in the project expressed that the teachers connected concepts in Math and science to daily life. One student remarked, "Well, for instance, sometimes when I had math it tended to be a little abstract and you might have wondered what you would use this for?" As result of this experience, however, students expressed they "experienced" a concept rather than just "reading" about it.

Another example was the "Roller Coaster Project." This project allowed students to see the "science" behind roller coasters. It culminated in a trip to a local amusement park. Students did research on roller coasters and then, during their visit to the park, they divided up into teams and collected data during their rides. They used this data to answer questions about the rides and what they experienced. A student in the project summarized it this way: "A teacher that uses technology teaches differently because they don't necessarily teach in the traditional teaching manner. They seem to bring more of the outside world into the school."

Conclusion

In conclusion, visualization is not an easy task. Technology, and access to technology, is an important component for developing visualization. Both students and teachers see visualization as a common link that helps all students have access to the concepts. The group work in the classroom also facilitates learning because it provides a support group and another means to help students learn. Students, who may just "tune out" during a lecture and may be "left behind" as a result, now have the opportunity to be actively engaged in the learning process through visualization and group work.

Technology is also important for teachers as part of their professional development. Teachers need to learn how to use current software packages in their fields and keep up with developments in their field. Technology is one of the factors that is fueling the changes we're seeing in the world by providing an expanded information base. No longer is information confined to physical libraries. The Internet provides access to libraries and resources worldwide. Students and teachers must learn to how to access and use the information that is available if they are to succeed.

While both teachers and students grew academically and professionally, teachers found that teachers who take on this challenge must be willing to view teaching just a little differently. They must be comfortable with restructuring the curriculum, trying different methods, tolerating just a little more "noise" in their classrooms and working through the frustration when the technology just didn't work. Students also faced the challenges associated with discovery learning that sometimes there might not be a "right" answer to a problem, and that the teacher may not have all the answers. Through visualization, students and teachers can learn together to develop shared knowledge that encourages students to develop a sound understanding of the "big concepts" in math and science and how math and science is related to their lives.

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