CRAFTING THE TECHNOLOGICAL SOLUTIONS IN HIGH SCHOOL SCIENCE AND MATHEMATIC TEACHING AND LEARNING: MATTHEW EFFECTS AND THE DIGITAL DIVIDE

Yvelyne Germain-McCarthy, Dorothy Haggerty, Cory Buxton,
Richard B. Speaker, Jr.

ABSTRACT
This paper examines the practices and concepts used in teaching high school science and mathematics concepts (grade 9 - 12) which integrate computer and multimedia technologies and hands-on activities into discipline-based science and mathematics classrooms, using standards from national science organizations, the National Council of teachers of Mathematics and the International Society for Technology in Education. Observational data is reported on four sites, mathematics and science classrooms where various levels of technology integration are present. The contrast in technology use in science and mathematics teaching is illustrated by the differences at the high schools. The digital divide continues to grow in the science and mathematics classrooms at the high school level. This paper is part of the symposium for teachers titled: Technologies for Teaching Science and Mathematics in the K-12 Schools: Reviews, Observations and Directions for Practice in the Southern United States.

KEY WORDS
Technology integration, secondary, high school, science teaching, mathematics teaching, access to technology

INTRODUCTION

Many students today perceive mathematics and science as merely a bunch of numbers to substitute in formulas to solve a problem and facts to memorize. More often than not, the mathematics and science problems they are asked to solve are not their problems, nor do they come close to something they are interested in pursuing. Knowing that this approach to the teaching and learning of mathematics has led to disinterest in pursuing mathematics and increased mathematics anxiety in many students, the National Council of Teachers of Mathematics, International Society for Technology in Education and various science organization have published standards documents (ISTE, 2002; NCTM, n.d.; NSES, n.d.) to guide content teaching, the pedagogy of mathematics and science classrooms, and the evaluation of mathematics curricula. In April 2000, NCTM revised the standards to place greater focus on technology and unveiled its *Principles and Standards for School Mathematics*. The basis for these documents is to foster the awareness and application of two primary goals: one, that all students should experience effective mathematics and science teaching, and two, that the focus of mathematics and science instruction should be to help students develop a deep understanding of important mathematics and science concepts. Critical to the attainment of these goals is a balanced curriculum taught by teachers who have a strong content and pedagogical background and believe that all students can learn challenging mathematics and science.

Standards provide guidelines for creating such a balanced curriculum. In mathematics, they consists of six principles and 10 standards that describe characteristics of quality instructional programs and valued goals for students' mathematical knowledge. At the high school level, students are expected to study four years of mathematics regardless of their chosen career. Six characteristics called guiding principles, are offered as basic tenets on which to establish quality programs and guide decisions about mathematics instruction at all levels. These guiding principles focus on: equity, curriculum, teaching, learning, assessment and technology. Ten standards address the question: What mathematical content and processes should students know and be able to do as they progress through school? Of the ten, five are mathematical content standards that describe what students should know and be able to do within the areas of number and operations, algebra, geometry, measurement, data analysis, probability, and statistics. The other five are process standards that address students' acquisition, growth in, and use of mathematical knowledge in the areas of problem solving, reasoning, connections, communication, and representation models. Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. Similar principles and standards are available for science teachers (NCTM, n.d.).

METHODOLOGY

The authors have long standing interests in technology integration into instruction. They have participated in the New Orleans Consortium for Technology Integration and Implementation in Teacher Education (NOCTIITE, Speaker, 2002), studying and observing teaching with technology in the schools. We have collected various streams of evaluation data related to technology in the teaching of science and mathematics and analyzed it for technology integration in teaching. This data is qualitative in nature, leading to narrative analysis (Bruner, 1990, 1996; Clandinin, & Connelley, 1999), case study methods (Merriam, 1999), and portraiture (Lawrence-Lightfoot, & Davis, 2001) within a post-modern, interpretivist stance (Foucault, 1972). Each observer acts as a tool recording and interpreting the situated events in classroom contexts. The goal of the evaluation system for NOCTIITE was to provide both formative and summative information about the ongoing and cumulative effect of the project. Thus, the system was designed to summarize, analyze, and interpret data collected systematically within and across the three years of the project itself by various stakeholders and the follow-up years beyond the scope of the project. For this paper, we provide three descriptive cases to elucidate the teaching of sciences and mathematics with technology in high school classroom. The methodology for this paper is more fully discussed in Speaker (2003).

Technology Framework

To function in a technological environment, the teacher needs control over a variety of technologies and access to others. This implies that the teacher needs equipment with software which is easy to use, input systems, internet access, a plan for the level of learner activity with technology and various multimedia, the abilities to evaluate websites and communicate with students and their parents, basic troubleshooting skills with technology and an awareness of the ethical and legal issues for using technology. Thus, we have created a framework with the following categories: Equipment, Software, Ease of Software Use, Input System Use, Internet Use, Level of learner Activity with Technology, Multimedia, WebSite Evaluation, E-mail for Students, Communication with Parents and the School Community, Trouble Shooting, and Ethical and Legal Issues.

For children in grade nine through twelve (high school in the U.S.), the emphasis of technology must be as a transparent and flexible tool for teacher and student use, which the teacher uses to support a developmentally appropriate curriculum in a supportive learning environment. Equipment in the classroom should include computers, projection devices such as a large screen television connected to a computer or a powerful data projector, printers (both black and white and color laser printers are ideal), floppy drives, CD-drives, web connections, scanners and graphing calculators with advanced functions. The teacher must be familiar with issues related to the number of computers in the classroom and planning for their appropriate use with. Computers, laptops, projection devices, printers, scanners, probes, floppy drives, CD-drives, web connections, and CD and DVD burners should all be present; however, high school teachers will always have issues about the number of computers in the classroom and how to use them effectively.

High school students should be able to engage in sophisticated technology use to support their learning. Any published software should be useable including PowerPoint, Word, Excel, Flash, image editing, video editing, sound editing, programming languages, full web design packages, systems, scripts, and Java, although individuals are likely to have advanced skills in only a few of these types of software because of personal interests and abilities. Students should not require easy software for personal and project presentations and web pages because of continuous learning of technology integrated in their studies from early grades; thus, their projects can include presentations and web pages incorporating images, video, forms, animations, and cookies to gather data about web page visitors. They should be proficient with input devices, formats, security and initial business concepts relating to e-commerce and web design, building websites with chats, forums, forms and e-mail. They can evaluate websites for their use with difference populations and for specific purposes. These students should handle much of the web work for their schools and classes, maintaining communications between the school, parents and the community at large.

The following brief descriptions show integration of technology at the high school levels.

Case 1 -- Mathematics: Claudia Carter, Mississippi: How a Rumor Spreads-An Introduction to Logistics Curves (this is adapted from Germain-McCarthy, 1999)
One of the initiatives of the National Science Foundation is to fund projects to create reformed curricula. Claudia was invited to join a team of writers for a project called ARISE written by COMAP, Inc. (Consortium of Mathematics and its Applications). COMAP develops projects so that the mathematics content "arises" out of given problem situations. Claudia's lesson on investigating exponential and logarithmic functions was inspired by the work she did as part of this team.

Beginning with the question: "Suppose I told you a really juicy rumor about our principal. How fast would this rumor spread?" Students smile; having gotten their attention, Claudia distributes a handout to students. Part A of the handout requires students to write a description of their guesses on how a rumor might spread and to sketch a graph of the total number of people who have heard the rumor as a function of time. Claudia asks, "What do you think happens in the school over a short period of time, say in about a week?" As students work independently to answer this question, Claudia circulates about the room. She notes that for the most part, students write a correct description, stating that the rate at which the rumor spreads tends to slow down as there are fewer and fewer people to tell. However, nearly all students incorrectly graph a curve resembling an exponential function, in which the number of people increases without bound. These observations will guide Claudia's development of the lesson.

Through a general discussion, she elicits from students the factors that affect how this rumor spreads. Students comment that some aspects of the rumor would probably change, and that how fast it spreads depends on how many students each person tells. "Let's assume that each person tells one other person each day. We can use the random number generator of a graphing calculator to simulate the spread of a rumor," she tells them. Because the class has only 13 students, she assigns two different random numbers from 1 to 26 to each student and programs the calculator to randomly generate these numbers.

She tells students to begin Part B of the handout. They are asked to predict the numbers of turns it will take the calculator to spread the rumor to everyone in the class, and then to keep a running tally of the total number of people who have heard the rumor. To help students understand the process, Claudia asks a series of questions (student responses are shown in parentheses).

- If we start with turn 1 representing the person who starts the rumor, what can we enter in the chart? (The number of turns is zero, new people is zero, and total number is one.)
- If we assume that each person tells one other person at every turn, how many random numbers should the calculator generate for the next three turns? (The second turn requires one random number, the third turn requires two, and the fourth requires four.)
- At the fifth turn, should I expect that a total of 16 people will have heard the rumor? Why? (No, because some numbers may be repeated—the person you choose to tell may have already heard the rumor!)

As Claudia calls out the numbers generated by the calculator to represent those who are told the rumor, she asks only those students whose number is called for the first time to raise their hands. Student reactions vary at this point. Some are excited to be included. One student whose number was generated last pretended to look upset, and commented that he was always the last to know!" Finally, she asks them to comment on how their predictions in Part A compare with the calculator's results. Students are generally surprised to see how far off their predictions were. Most students thought the rumor would have taken more time to spread.

Next they graph the table, and compare the graph to their sketch in Part A. Many had graphed different curves; Claudia asks them to describe their reasoning. Students' misconceptions become clear as they try to justify their graphs.

Returning to the calculator's simulation graph, Claudia asks students to describe how a graph depicting the number of people buying the current fad might fit the graph, and to indicate the part of this curve at which a store manager would want to have the greatest and smallest supply of the fad. Once students' responses indicate a good understanding of the connection between the various parts of the curve and the real-life situation, Claudia asks them to describe the general shape of such a graph and to give its name. One student correctly identifies its shape as that of the letter S, and Claudia tells them that curves, which level off in this S shape, are called logistic curves.

Too often, Claudia feels, students' only experiences with collecting data occur in science labs, where time constraints often reduce the opportunity to collect multiple sets of data. As a result, some students conclude that one set of data is enough to make an accurate prediction. To correct this misperception, In Part C of this lesson Claudia uses a second calculator to repeat the simulation five times.

Her next question, "Suppose I program the calculator to do five simulations for a class of 35, instead of just one simulation. Would that make a difference," prompts a discussion about the law of large numbers and variability in data: The more data collected, the greater the chance of balancing the effects of observations that are not representative of the data as a whole. Having highlighted the need for simulations that can run the experiment several times, Claudia asks students to complete Part C of the handout, comparing the calculator's graph of the simulation and the graph the class generated in Part B. The final discussion centers about other real-life experiences that could be modeled by this curve. The students are quick to point out examples of the spread of disease, and population growth. She invites students to comment and asks what other factors they think might limit population growth. Students' suggestions launch a discussion on the impact of space on growth and on why it is sometimes necessary to transport animals to different locations. Then Claudia asks students to think about why it can be difficult to recognize a logistic curve very early on. Students review the properties of the graphs they have drawn. They conclude that the initial slow growth rate is deceptive. Time must pass before the curve begins to rise sharply, and again before it levels off. "What is the population of the world today? Which curve best represents the world's population trend today?" Claudia's final questions have opened the door to further explorations of a rich topic.

Case 2 -- Mathematics: Cynthia Sutherlin, Arkansas- Mathematical Modeling of Linear Functions in the Sciences (adapted from *Germain-McCarthy, 1999*)
During the summer of 1996, Cynthia Sutherlin took part in the Arkansas Crusades, which is part of Arkansas' State Initiative Program. As a member of a team consisting of two mathematics and three science teachers, she helped to develop an Algebra 2 mathematics and science unit to approach graphing linear equations through data collected from real-world applications. The unit's perspective is that of mathematics as the language of science.

Preparing for the Lab
To begin the lab, Cynthia informs students that they will form groups to explore the relationship between the amount of dissolved solute and the freezing point of a liquid. Students look a bit perplex

and one says, "But this is not a science class!" He is right. What is more, Cynthia's class does not look like a science class. Her class is not equipped with typical science materials such as test tubes or balances. It is a regular room with only two laboratory advantages: the desks have a flat top, and a sink can be found across the hall in the janitor's room. She does have a classroom set of graphing calculators and one Calculator Based Lab unit (CBL) to collect data. To make her lab lesson possible, she communicates frequently with science teachers in her school who willingly let her borrow equipment in addition to helping her better understand [the] lab's science concepts as described in the teacher notes written by the team who originally wrote the unit.

Engaging Students
She begins the lesson by saying, "Tell me all you know about road conditions and mobility of cars on such days." Students talk about icy and dangerous roads and cars stalling or not starting. When she asks for preventative measures generally taken against such events happening, they suggest dropping salt on the roads or putting antifreeze in cars. She notes them on the board and comments, "Salt, or sodium chloride, is added to roads so they will be wet, not icy, at lower temperatures. Salt, as we shall see, is added to the ice when preparing homemade ice cream so the mixture will freeze. Ethylene glycol or other antifreeze substances are added to the water in a car's cooling system to prevent overheating in summer and freezing in winter. All of these are examples of dissolving solutes in water." Students express some confusion about how salt keeps water from freezing and does quite the opposite for ice cream. Cynthia tells them that the basis for the day's lab is to explain why that happens. She directs students to the back of the class where she has prepared the equipment and lab sheet necessary for the day's experiment.

Once in their groups, students partition responsibilities among themselves and Cynthia monitors to be sure that each student has an assignment: some are wrapping the ice bag in a towel to crush it; others are measuring salt, checking materials or getting water. Because she has only one CBL, she assigns each group to do just one measurement with a fixed amount of salt and to take turns collecting this data. Since students are moving from station to station, taking the temperature does not cause too great a bottleneck, and it takes each group only a couple of minutes to do each reading. Students carefully follow the procedure for twice measuring the temperature of ice water as salt content is gradually increased. They first record water temperature with no salt. Then each adds their assigned amount of salt and takes the second reading. They keep a record of corresponding temperature changes in a two-column table. Cynthia's also asks each group to write their results on the board to form a composite list for later analysis. For homework, she asks them to examine the list, note variations and reflect on possible causes: "which are reasonable? Can we continue to work with this data? Find the mean, mode and average of the data." These questions are good entry points for defining reviewing basic measures of central tendency because Cynthia wants to make students aware that data often do not conform to expectations-especially since students will measure incorrectly. It is also a good opportunity to work with some statistics. For example, she gets them to brainstorm on whether to use the mean, median, or mode for particular problems.

During the next class, she has students share responses from the homework and come to an agreement on what to use as a reasonable set of data. Before having students plot the data on a grid, she asks them to determine what scales would work well and on which axes to plot the variables. Deciding on having the vertical axis for amount of salt, and the horizontal for temperature, students plot the data, estimate and sketch the line of best fit, and determine its equation from its slope and intercept. They do all this without the help of a graphing calculator because, as Cynthia writes, "We use them to do graphs in other lessons, but not in this one since my objective is to develop and enhance their ability to graph by hand first."

Case 3 – Kate, Louisiana-Predictions and Decisions: Inquiry into Hurricanes using Interactive Technology
Kate is currently using a Wireless Computer Lab from a technology grant received by her school. Her classes have access to 24 laptop computers kept in a large self-contained cabinet unit. This unit is

connected to the Internet and a laser jet printer. Students are able to use this equipment once a week in her classroom. Other teachers share the equipment throughout the school. She also uses stationary computers in her classroom for students to research various topics. Her classroom instruction includes the use of Power point presentations and a large screen TV for ELMO projections and as a large monitor for the computer.

For her Weathereye Hurricane Interactive Activity, her objectives were:

- Interpret data and plot a graph showing the path of a hurricane;
- Describe the meteorological characteristics of a category 5 hurricane;
- Use problem solving and decision making skills to complete a press release.

Kate introduced the lesson by showing a photo of a category 5 hurricane on the large screen TV using the ELMO desktop presenter. While students viewed the photo, she played a CD of the wind howling during a hurricane. The students became very interested as the lesson took place in October during hurricane season. A chart was used to determine what the students know about hurricanes and what they want to learn about them. They concluded the lesson by filling in the "what I learned" part of the chart. She then handed out the laptop computers and the directions for the interactive activity.

The students worked individually on the activities, including a guided lesson using graphs, weather maps, and statistics to track historical hurricane paths. Each student acted as the Mayor of Pensacola, Florida, during a hurricane. As the hurricane made its way through the Gulf of Mexico towards the coast of Florida, geographical coordinates and meteorological statistics are given. Students were instructed to chart the progress on a hurricane tracking map, complete 2 quizzes to test their general knowledge of the information, and complete a press release to announce executive decisions to evacuate or not. Upon completion of the work, students were issued a password to discover the real life path of the hurricane used in the activity and its related damage to the coast of Pensacola.

This Internet activity assesses content knowledge through the quizzes, graphing skills, and critical thinking skills for analysis of the data for the press release. After the activity, students will write a reflection paper describing the relevancy of the project and supporting their decisions as acting mayor.

Case 4 -- Science: A Virtual Fetal Pig Dissection

Maloney (2002a) provides research into the effects of a virtual fetal pig dissection which demonstrated increased knowledge acquisition of a virtual setting over the full hands-on dissection. In her work, she had female high school biology students use computers to move through a virtual dissection that is available on the web (Malone, 2002b). Students in the biology class encountered each of the major organ systems through a variety of images and labeling activities then took both practical and knowledge tests. These students were able to examine various fetal pigs and review the entire process both visually and verbally from any computer location, providing them with a new method of studying that did not only rely on notes, laboratory manuals and text books.

The reactions of these students to the virtual dissection experiences were remarkably similar to those of hands-on students: For instance, in the virtual condition:

> students stated that the dissection was "complicated," "chaotic," "horrible," "frustrating," "annoying," and "stressful." One of these students summed up these thoughts by saying "It was very stressful and I was aggravated. You didn't know where the body parts were on the computer. I was very stressed out with it, and I needed a lot of explanations." One student who performed a virtual dissection disagreed and felt that you could see the organs clearer when looking at an actual specimen. Another of these students said "It was frustrating because the packet didn't match. It was the first time for the teachers and both the teachers and students didn't know what to do." One student disagreed with this idea by stating that the teacher "did a good job, I feel so bad we stressed her out." (p. 86).

Her six days of virtual lessons covered external structures; neck, mouth and throat organs; thoracic cavity organs (heart and lungs), the digestive system; the urogenital system; and the nervous system of the fetal pig. Students took a practical test based on a set of PowerPoint slides and a pencil and paper knowledge test. The greatest difficulty encountered was the lack of computers in the science laboratory, so the students went to a bank of fifteen computers in the school library to complete their dissection activities.

CONCLUDING REMARKS

Educational technology can be used either to support inquiry-based teaching of mathematics and sciences of to maintain traditional teaching methods. Each of these cases highlight an individual teacher's inquiry-based pedagogy using technology to support instructional efforts. In the case of the logistical curves, Claudia engaged students in a topic that found stimulating and challenging, while providing the necessary framework to facilitate students' exploration of the speed at which rumors spread and the resulting shape of the curve. For exploration of linear functions, Cynthia use tools more commonly found in science classrooms than the mathematics classroom (e.g., calculator based laboratory and probes) to investigate the topic of freezing points in a context relevant to student experiences. In interactive hurricane tracking, computer technology supported the role-play activity by providing the "mayor" with realistic data needed to make informed decisions concerning hurricane evacuation. Finally, with the virtual pig dissection, technology was a mirror to a traditional laboratory activity, providing direction for how dissection activities may be made more inquiry-based in the future.

Standards-based science and mathematics instruction aims to create classroom environments that foster a balance between content and process. Technology should not usually be the focus of the lesson, but rather a support for teachers as they attempt to implement new methods. Each of these cases provides example of effective practice and technology integration in the high school, demonstrating a level of technological competence that only comes from substantial training and administrative support. Unfortunately, while the availability of educational technologies is spreading rapidly, the support structures are not keeping pace.

These cases provide a range of multimedia and technological applications to science and mathematics teaching, integrating the concepts and content with transparent technology use. The goals of the teachers are to make technology a useful tool in developing the mathematics and science concepts, rather than an end in itself. These teachers use graphing calculators, computers, whole class presentations on large monitors, existent desk-top computer laboratories and portable wireless laboratories as a communication tool serving the lessons and motivating the students, saving labor and allowing learners to see multiple examples which could not be available if pencil and paper calculations and graphing, but these teachers incorporate the technology within standards-based and problem-solving setting where learners must observe, brainstorm, read, write and solve problems.

Not every classroom has access to the latest equipment or the internet; instead, teachers and school administrators are searching for the funds to build and train teachers to incorporate technological tools into their high school science and mathematics classrooms. While able teachers are making use of what they already have, teacher educators must continue points in directions that allow teachers to craft solutions to the digital divide and to ensure that all student have easy access to the information and technological processes which modern multimedia technology provides.

REFERENCES

Bruner, J. S. (1990). Acts of meaning. Cambridge, MA: Harvard University.

Bruner, J. S. (1996). The culture of education. Cambridge, MA: Harvard University.

Clandinin, D. J., & Connelley, F. M. (1999). Narrative Inquiry: Experience and Story in Qualitative Research. Somerset, NJ: Jossey-Bass.

Foucault, M. (1972). The archaeology of knowledge. [Trans. M. Smith.] New York: Pantheon.

Germain-McCarthy. (1999). Bringing The NCTM Standards To Life: Exemplary Practices from High School. New City, N. Y: Eye on Education.

ISTE (International Society for Technology in Education). (2002). Available: http://www.iste.org/.

NCTM (National Council of Teachers of Mathematics). Standards. Available: http://www.nctm.org/standards/.

NSES (National Science Education Standards). Available: http://stills.nap.edu/readingroom/books/intronses/, http://www.allstar.fiu.edu/aerojava/nasci912.htm.

Lawrence-Lightfoot, S., & Davis, J. H. (2001). The Art and Science of Portraiture. Somerset, NJ: Jossey-Bass.

Merriam, S. B. (1999). Qualitative research and case study applications in Education. Somerset, NJ: Jossey-Bass.

Maloney, R. S. (2002a, December). Virtual Fetal Pig Dissection as an Agent of Knowledge Acquisition and Attitudinal Change in Female High School Biology Students Unpublished dissertation. University of New Orleans.

Maloney, R. S. (2002b). An On-line Virtual Fetal Pig Dissection. Available: http://tec.uno.edu/George/Class/2002Fall/EDCI4993603/webSites/BMaloney/pigdissection.htm

Speaker, R. B., Jr. (2003). Technologies for teaching science and mathematics in the K-12 schools: Reviews, observations and directions for practice in the southern United States. Paper to be presented at the conference of Computer-based learning in Sciences (CBLIS). Nicosia, Cyprus. (this volume).

Speaker, R. B., Jr. (2002). NOCTIITE Webpages. Available: http://tec.uno.edu/NOCTIITE

Yvelyne Germain-McCarthy, Dorothy Haggerty, Cory Buxton, Richard B. Speaker, Jr.
University of New Orleans
Department of C&I, Ed 342J
New Orleans, Louisiana, USA 70148
E-mail: ygermain@uno.edu, dhaggert@uno.edu, cbuxton@uno.edu, rspeaker@uno.edu