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ABSTRACT

The objective of this paper is to show how science, writing and technology can be successfully integrated to maximize learning for all students. A recent research study infusing the writing process into hands on science lessons will be discussed, along with recommendations on the use of technology to support instruction in the areas of science and writing. Technology will be presented both as an extension of science through the use of Science-Technology-Society investigations and as a tool for teaching and learning. Strategies for supporting all learners in science, writing and technology will be emphasized. An overview of the state of technology today in the United States will be presented, as well as the U.S. National Educational Standards for Science, Writing and Technology. Technologies support learning in a variety of ways. The connecting of U.S. classrooms to the Internet and expansion of numbers of computers accessible by students and teachers has led to increased access to information, online learning environments and tools to support collaboration and communication. Word processing and desktop publishing have made writing engaging and easy to edit, and students publish professional looking products. The development of digital technology has expanded the use of video, photography and simulations supporting active learning environments. These emerging technologies address multiple learning styles and active participation leading to knowledge construction and increased understanding of science. Other technologies such as videoconferencing and virtual environments are leading to new thinking about how students can connect to experts, peers, and teachers. The authors will describe examples of how technology, science and writing have been used in effective learning environments in K-12 education. These examples can be modified to fit the specific needs of teachers and learners. The researchers are currently implementing science model projects that are included in the presentation. (Author/YDS)

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# K-12 INSTRUCTION IN THE UNITED STATES: INTEGRATING NATIONAL STANDARDS FOR SCIENCE AND WRITING THROUGH EMERGING TECHNOLOGIES



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**Abstract**

The objective of this paper is to show how science, writing and technology can be successfully integrated to maximize learning for all students. A recent research study infusing the writing process into hands-on science lessons will be discussed, along with recommendations on the use of technology to support instruction in the areas of science and writing. Technology will be presented both as an extension of science through the use of Science-Technology-Society investigations and as a tool for teaching and learning. Strategies for supporting all learners in science, writing and technology will be emphasized. An overview of the state of technology today in the United States will be presented, as well as the U.S. National Educational Standards for Science, Writing and Technology.

Technologies support learning in a variety of ways. The connecting of U.S. classrooms to the Internet and expansion of numbers of computers accessible by students and teachers has led to increased access to information, online learning environments and tools to support collaboration and communication. Word processing and desktop publishing have made writing engaging and easy to edit, and students publish professional looking products. The development of digital technology has expanded the use of video, photography and simulations supporting active learning environments. These emerging technologies address multiple learning styles and active participation leading to knowledge construction and increased understanding of science. Other technologies such as videoconferencing and virtual environments are leading to new thinking about how students can connect to experts, peers and teachers.

The authors will describe examples of how technology, science and writing have been used in effective learning environments in K-12 education. These examples can be modified to fit the specific needs of teachers and learners. The researchers are currently implementing science model projects that will be included in the presentation.

## Introduction

Science and technology go hand-in-hand. It is hard to imagine science without technology, or teaching science without a focus on technology. National standards in the United States call for the use of technology to support learning. The National Science Education Standards include technology as an important component of science teaching. This focus addresses the need to prepare students for their future in which more than 60% of jobs will require advanced skills in technology (U.S. Department of Education, 1998). The partnership of hands-on science, constructivist pedagogy and technology-supported activities can lead to improved student achievement and accountability for continuous improvement (CEO Forum, 2001). Using technology in science not only helps make science relevant to everyday life, it can also assist students in gaining greater understanding of science concepts. But how are we using technology in the science classroom? Is technology being used to help children develop their knowledge and expertise in content areas such as science? How might teachers accomplish this, and at the same time, work with students to improve their writing skills?

Our purpose is to demonstrate how science teaching, writing skill development, and the use of technology can be integrated in the K-12 classroom for the purpose of optimum learning in science and improvement in writing skills. The paper is divided into three major areas: science education, writing instruction and educational technology. In the final part of the paper, we discuss the relationship among the components and how all three may be integrated to positively influence teaching and learning.

First, we will introduce the National Science Education Standards and briefly discuss the standards that are related to science teaching, science content and science education programs. In this section, technology will be introduced as an extension of science instruction through Science-Technology-Society investigations. The second part of the paper describes a "snapshot" of writing as a part of K-12 classes. We have included the writing process as a focus because of the importance of literacy in today's classrooms and because of the additional opportunities that writing offers as a way to learn science. We present National Standards for the English Language Arts that include writing. Examples of writing activities to infuse in science classes are provided.

Next, we have included a description of educational technology use in U.S. classrooms. The National Educational Technology Standards are summarized, and are followed by a discussion of how technology supports constructivist teaching and learning practices. Examples of how technology is used as a tool for science instruction are described. Finally, we bring the three areas of science, writing and technology together, and discuss how integration in constructivist classrooms is important to prepare students for their futures.

## Science Education

### The National Science Education (NSE) Standards

The NSES standards (http://search.nap.edu/readingroom/books/nses/html/) present a vision of a scientifically literate populace. They outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels. They describe an educational system in which all students demonstrate high levels of performance, in which teachers are empowered to make decisions for effective learning, in which interlocking communities of teachers and students are focused on learning science, and in which supportive educational programs and systems nurture achievement.

The intent of the NSE Standards can be expressed in a single phrase: Science standards for all students. Different students will achieve understanding in different ways, and different students will achieve different degrees of depth and breadth of understanding depending on interest, ability, and context. But all students can develop the knowledge and skills described in the Standards, even as some students go well beyond these levels. The National Science Education Standards are presented in six categories:

- Standards for science teaching
- Standards for professional development for teachers of science
- Standards for assessment in science education
- Standards for science content
- Standards for science education programs
- Standards for science education systems

This paper focuses on science, writing and use of technology in individual classrooms and learning situations. Therefore, NSE Standards related to science teaching, science content, and science education programs are most relevant. Overviews of the standards are presented below.

### Science Teaching Standards.

The science teaching standards describe what teachers of science at all grade levels should know and be able to do. They are divided into six areas:

- The planning of inquiry-based science programs
- The actions taken to guide and facilitate student learning
- The assessments made of teaching and student learning
- The development of environments that enable students to learn science
- The creation of communities of science learners
- The planning and development of the school science program

Effective teaching is at the heart of science education, which is why the science teaching standards are presented first. Good teachers of science create environments in which they and their students work together as active learners. They are continually expanding theoretical and practical knowledge about science, learning, and science teaching. They use assessments of students and of their own teaching to plan and conduct their teaching. They build strong, sustained relationships with students that are grounded in their knowledge of students' similarities and differences and they are active as members of science-learning communities.

**Science Content Standards.**
The science content standards outline what students should know, understand, and be able to do in the natural sciences over the course of K-12 education. They are divided into eight categories:

- Unifying concepts and processes in science.
- Science as inquiry.
- Physical science.
- Life science.
- Earth and space science.
- Science and technology.
- Science in personal and social perspective.
- History and nature of science.

Each content standard states that the content is to be understood or certain abilities are to be developed. The standards refer to broad areas of content, such as objects in the sky, the interdependence of organisms, or the nature of scientific knowledge.

**Science Education Program Standards.**
The science education program standards describe the conditions necessary for quality school science programs. They focus on six areas:

- The consistency of the science program with the other standards and across grade levels.
- The inclusion of all content standards in a variety of curricula that are developmentally appropriate, interesting, relevant to student's lives, organized around inquiry, and connected with other school subjects.
- The coordination of the science program with mathematics education.
- The provision of appropriate and sufficient resources to all students.
- The provision of equitable opportunities for all students to learn the standards.
- The development of communities that encourage, support, and sustain teachers.

Program standards deal with issues at the school and district level that relate to opportunities for students to learn and opportunities for teachers to teach science. The first three standards address individuals and groups responsible for the design, development, selection, and adaptation of science programs—including teachers, curriculum directors, administrators, publishers, and school committees. The last three standards describe the conditions necessary if science programs are to provide appropriate opportunities for all students to learn science.

**Science-Technology-Society**
A Science and Technology Standard is included in the content standards of the National Science Education Standards to show the relationship between the two fields. The science and technology standard establishes connections between the natural and designed worlds and provides students with opportunities to develop decision-making abilities. It is not a standard for technology education; rather, it emphasizes abilities associated with the process of design and fundamental understandings about the enterprise of science and its various linkages with technology (http://www.nap.edu/readingroom/books/nses/html/6a.html#sts).

Science-Technology-Society (STS) is an interdisciplinary approach to teaching science that integrates the studies of science, technology and society in thematic or project strategies. STS focuses on the influence of each of these subjects on each other, and it helps students understand what science and technology are and the role they play in our lives. STS presents scientific problems for students to solve that are based on issues that are relevant to them. STS topics may include various ecological and environmental issues, energy, health, population, resources and other topics that citizens should understand in order to be active and responsible members of our society who are willing to take actions for improving their lives and world.

STS is grounded in constructivism, as students begin to understand the science concepts and processes because they are relevant to daily lives. In STS investigations, children identify relevant issues, and participate in deciding what they need to know and do as they research explanations and answers (Martin, 2000). Children and teachers are co-inquirers as they collaborate in deciding what should be studied, how to proceed, and how they will get involved. New questions and problems are encountered along the way.

## Writing Instruction

### Writing Across the Curriculum

Many K-12 schools in the U.S. currently emphasize writing across the curriculum. Some elementary schools have daily writing prompts that all teachers use as catalysts for students to practice and improve their writing. In states such as California and Texas that have many English language learners, literacy is the major focus of instruction in elementary schools. Reading and writing are highlighted in every class in every grade level. Some universities, such as the institution of the authors of this paper, have a universal writing requirement; every class has a writing component. The authors of this paper have identified writing as a way to learn science and as an important component of constructivist classrooms. Ways to infuse writing activities into hands-on science classes are presented.

### National Standards for the English Language Arts

Writing is a major focus in U.S. classrooms, both as a component of literacy and as a way to learn and demonstrate knowledge. The writing process is now being taught in all grade levels, so that students graduate from high school with confidence and competence in the writing process. Below are the National Standards for the English Language Arts (http://www.ncte.org/standards/) that include standards in writing. The vision guiding these standards is that all students must have the opportunities and resources to develop the language skills they need to pursue life's goals and to participate fully as informed, productive members of society. These standards assume that literacy growth begins before children enter school as they experience and experiment with literacy activities—reading and writing, and associating spoken words with their graphic representations. The standards encourage the development of curriculum and instruction that make productive use of the emerging literacy abilities that children bring to school.

1. Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features.
2. Students adjust their use of spoken, written, and visual language to communicate effectively with a variety of audiences and for different purposes.
3. Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.
4. Students apply knowledge of language structure, language conventions, media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts.
5. Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.
6. Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
7. Students develop an understanding of and respect for diversity in language use, patterns, and dialects across cultures, ethnic groups, geographic regions, and social roles.
8. Students whose first language is not English make use of their first language to develop competency in the English language arts and to develop understanding of content across the curriculum.
9. Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.
10. Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

### Infusing Writing Activities in Science Instruction

Writing is considered an important part of the science curriculum. Clear communication of thoughts and ideas is imperative in science (Ediger, 1994/1995). Writing has been shown to aid students in learning and reflecting during science instruction. Writing-to-learn is a viable constructivist process and compliments inquiry science teaching methodologies. Writing can provide new avenues for students to understand science, and should not simply be used to assess past learning (Hand, Prain & Vance, 1999).

A research project on the integration of writing processes with science instruction was conducted last year by one of the authors of this paper. The study investigated student achievement in science and writing, when hands-on science lessons were infused with extensive writing activities in a 6th grade classroom. In the study, student achievement in a class in which writing was linked to hands-on science was compared to student achievement in a class experiencing hands-on science without the integration of extensive writing assignments. The research included pre-testing, post-testing and performance-based assessments in science and writing. Results showed that it is beneficial to integrate science teaching and writing processes; the integration helps students in their understanding of science concepts and in their writing skill development. Different types of writing were included in the science lessons in the study. Examples of these and other writing activities are described in the remainder of this section.

Scarnati and Weller (1992) suggest that narration, description, explanation, and persuasion are the four basic methods of writing, and should be a student's main purpose in writing. Scarnati and Weller believed that there is "no better subject in which to practice these skills than science." By reporting on science activities, and keeping observations, students are in a situation in which a need for different writing forms exists. Students can keep experience charts, outline content, create concept maps, do book reports, keep journals and logs, write poetry, and produce writings at the beginning and end of classes in order to write as a way to learn science.

Keeping a science laboratory notebook is a viable way for students to practice and extend their writing abilities. Instead of completing data sheets in which they fill in information, students write out the complete investigations in sentence and paragraph format. They write out the scientific questions, their predictions, methodologies, results and conclusions. Rather than filling in charts, they design charts to record numerical results. The write descriptions and interpretations, and draw diagrams and pictures illustrating the procedures and results. Journal writing can also be used in science class, and may include learning goals, progress records, as well as summaries of content and further questions. Journal writing can be used to clarify understanding and to promote student-teacher communication. Children may keep journals on particular projects or units of study. Journals can be used to document change over time and experiences in fieldwork. Journal writing encourages students to observe and think like scientists.

Children of all ages can design a science project, and write and present a proposal which explains the question or project they are proposing, the materials and references needed, and the procedure they will follow. They can do the project and then write up the results and conclusions. Students can design creative inventions, creative applications of science concepts to real-world life, and physical and language metaphors to explain science concepts and process skills. They can also create their own science books by designing, writing and illustrating their understandings of topics in science. This makes science learning relevant to their own lives. They can share their books with other students.

Writing poetry can enhance young people's study of science. Teachers can read poetry aloud to students, in order to help them find their own way of expressing their awareness and understanding of science concepts and issues. Additionally, students can write an autobiography of themselves as scientists. Teachers will become aware of students' previous science experiences and how they felt about them.

Teachers can pose questions at the beginning of class that raise students' thinking to higher levels. The teacher may ask an open-end question, one that is opinion-based, and corresponds to what is being studied. Students can write the answer and share their answers. Students can produce learning logs at the end of class, and write a paragraph summarizing the day's lesson. They may list questions that the lesson made them want to ask.

They might write a quick-write paragraph describing what they learned. Students can complete exit cards on which they describe what happened in class that day. They can be asked to summarize, in one clear sentence, the main idea of the class on note cards. The next class, the authors of several of the cards can be asked to reproduce them on the board at the beginning of class. The class can discuss the sentences and compare thoughts on the previous lesson.

Focused free writing can be used to stir creativity. Students can write on a specific topic as quickly as possible, without worrying about grammar, punctuation, or style. Once individuals write a few lines, they will continue writing for five to fifteen minutes. Free writing can be used to generate ideas on a new topic, to review before a test, to create ideas before a discussion, and to find out students' knowledge on a topic. Students can make up their own who/what/when/where/why/how questions about a topic. Teams of students can then randomly select and answer questions in writing.

Educational technology will be the focus of the following section. The National Educational Technology Standards will be summarized, and examples of ways to infuse emerging technologies into science teaching and learning will be discussed. In the final section, we will discuss the integration of the three areas of science, writing and educational technology into K-12 classes.

## Educational Technology

### Technology Use in U.S. Classrooms

In 2000, 77% of classrooms in the US had computers connected to the Internet. The national average for students per instructional computer with access to the Internet was seven (CEO Forum, 2001).

This amazing statistic is evidence of the fact that most U.S. classrooms now include technology resources. Technology tools can include computers and a wide variety of equipment linking the computer to information. Video equipment is evolving as a key component of technology, which addresses a variety of applications expanding our use of technology in educational environments. Networking and infrastructure have connected computers to the Internet and a wide variety of tools have evolved to support communication through the use of chat rooms, threaded discussions, listservs, and interactive world wide web environments.

Teachers are beginning to use technology in the United States and to see the value of technology skills for preparing their students for future careers. A survey of teachers in early 2000 indicated that: 76% use computers daily for planning and/or instruction; 63% used the Internet for instruction and 77% had an email account (CEO Forum, 2001). Three ways teachers interact with students in the classroom include instructional approaches (web resources); interaction between faculty and students (virtual discussions) related to course content; and advice and counseling through email, cell phones, pagers and web tools. Teacher training has been expanded to include technology in pre-service experiences as well as ongoing professional development offered through school districts, county offices of education and higher education institutions.

According to a report from the CEO Forum (2001), digital content changes the learning process, allowing for greater levels of collaboration, inquiry, analysis and creativity. Technology can be used in schools for research, to solve problems, to analyze data, to collaborate and correspond with experts and to become content producers. Technology studies have shown that students who use technology for their schoolwork write better and perform better on tests. "Studies have shown that students who employed simulations, microcomputer-based laboratories, and video to connect science instruction to real-world problems outperformed students who employed traditional instructional methods alone" (CEO Forum, 2001). The explosion of digital technology has created a revolution similar to the "hands-on" movement of the 1960's and affecting science teacher education more than any curricular or instructional innovation in the past" (Flick & Bell, 2000).

### National Educational Technology Standards

The International Society for Technology in Education (ISTE, 2000) has developed National Educational Technology Standards (NETS) for Students (http://www.iste.org). In order for students to be prepared for a society with a technology base, it is important for students to develop skills in several areas:

1. Basic operations and concepts
    - Students demonstrate a sound understanding of the nature and operation of technology systems.
    - Students are proficient in the use of technology.
2. Social, ethical, and human issues
    - Students understand the ethical, cultural, and societal issues related to technology.
    - Students practice responsible use of technology systems, information, and software.
    - Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.
3. Technology productivity tools
    - Students use technology tools to enhance learning, increase productivity, and promote creativity.
    - Students use productivity tools to collaborate in constructing technology-enhanced models, preparing publications, and producing other creative works.
4. Technology communications tools
    - Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.
    - Students use a variety of media and formats to communicate information and ideas effectively to multip0le audiences.
5. Technology research tools
    - Students use technology to locate, evaluate, and collect information from a variety of sources.
    - Students use technology tools to process data and report results.
    - Students evaluate and select new information resources and technology innovations based on the appropriateness to specific tasks.
6. Technology problem-solving and decision-making tools
    - Students use technology resources for solving problems and making informed decisions.
    - Students employ technology in the development of strategies for solving problems in the real world.

Without a sequence of technology throughout the grades levels, it is impossible for teachers to plan for technology projects. Many students do not have technology at home and do not have an opportunity to expand their skills and have an equal opportunity to be prepared for college or professional careers. The issues of the digital divide are a concern for addressing equity in educational opportunities.

**Educational Technology and Constructivism**

In constructivist science classrooms, teachers and students learn side by side as they explore information, materials and resources. Tools are important for knowledge building; they help students gather data, organize information, share information and demonstrate their learning through writing. Emerging technologies provide many tools that support learning. The connecting of U.S. classrooms to the Internet and expansion of numbers of computers accessible by students and teachers has led to increased access to information, online learning environments and tools to support collaboration and communication. The development of digital technology has expanded the use of video, photography and simulations supporting active learning environments and addressing multiple learning styles and active participation leading to knowledge construction and increased understanding of science. Other technologies such as videoconferencing and virtual environments are leading to new thinking about how students can connect to experts, peers and teachers.

**Examples of Technology Use to Support Science Teaching**

Guidelines developed through the National Technology Leadership Initiative have been proposed to provide assistance in designing instruction and to guide applications of technology to support science teacher education reform (Flick & Bell, 2000). These guidelines include the following:

1. Technology should be introduced in the context of science content.
2. Technology should address worthwhile science with appropriate pedagogy.
3. Technology instruction in science should take advantage of the unique features of technology.
4. Technology should make scientific views more accessible.
5. Technology instruction should develop students' understanding of the relationship between technology and science.

In the paragraphs that follow, activities that support the guidelines and that infuse educational technology into science education are discussed.

Word processing and desktop publishing applications. Students can use word processing programs for written reports, essays, descriptions, and other writing forms. Mind-mapping software assists students in organizing their thoughts, brainstorming, and developing an outline. Children who use word processors exhibit higher quality and greater quantity of writing. Desktop publishing programs are word processing applications that allow children to put together newsletters, information pamphlets and similar products, with a professional appearance.

Tutorials and drill and practice software. Computer-based tutorials contain information that could be presented with a textbook, but may be more motivating than a text. These tutorials help students review information that they have not mastered, provide reinforcement of a skill, or provide additional time with a skill or concept. Drill and practice programs provide repeated practice and feedback to help students reach objectives. They focus on learning objectives, state the questions so that students know exactly what to do, give immediate feedback, and provide remediation.

Database management. Databases are systems that store and organize information. Students can use databases to generate and answer questions, formulate and test hypotheses and critically evaluate the results of inquiries. Through the computer, children can access commercial databases and information services, do collaborative research with others locally or around the word, get the latest weather and other science-related data. Students can also create their own database; this requires gathering information, analyzing it, categorizing it, and organizing it.

*Spreadsheet applications.* A spreadsheet is a ledger sheet into which data can be entered and stored. Numbers, words and a combination may be entered. Each cell has a reference based on its column and row. Numerical data from a spreadsheet may be converted into a graph. Data is represented in a form that makes it easy for pupils to see relationships between variables and to ask questions to be answered by referring to the spreadsheet. The spreadsheet and graphs are objects that help students analyze and understand their data.

*Multimedia presentations.* Students can create their own presentations to teach each other about concepts and processes. Students can be creative and demonstrate their understanding of a topic in unique ways to meet the learning objectives. The presentations can be saved and used for future reference or posted on the Internet for global sharing.

*Video.* Commercial and public television stations offer carefully designed instructional videos that are telecast during school hours so that schools can receive them and use them in appropriate classrooms (Martin, 2000). The Public Broadcasting System (PBS) regularly airs programs on science and nature; the Learning Channel airs programs on scientific topics; and the Weather Channel broadcasts daily 10-minute explanations of weather phenomena and offers documentary videos for use in classrooms. Students can produce their own videos demonstrating scientific concepts. They can be in charge of planning, directing and filming video clips explaining their scientific understandings to their peers.

*Threaded discussions.* Technology collaboration tools provided by the Internet include synchronous and asynchronous opportunities for discussions. Students can join discussions through listservs, bulletin boards, newsgroups, and computer-chat conferences about science topics.

*Videoconferencing.* Through the use of sound and video, classrooms are connected for the purpose of sharing knowledge, discussing perspectives, and asking questions. This tool can support the exchange of information between students or between student and mentor. Other technologies should be used in combination with this tool.

*Interactive video technology.* Interactive video technology (videodisks or compact disks) combines video pictures, microcomputer graphics, and text to present phenomena that otherwise would be inaccessible. This allows students to visualize chemical reactions or natural disasters like tornadoes that would otherwise be too hazardous, time-consuming, or expensive for students to observe. Examples of the use of video technology are for students to observe the eye of a hurricane or the colorful and violent reactions between dangerous chemicals.

*Microcomputer-based laboratories.* Microcomputer-based laboratories allow students to use computers as laboratory tools. The use of electronic probes and sensors allows students to use the computer to collect data and then import the information into a word processing system. They can collect accurate scientific data and complete multiple trials in a timely manner. Interfaced electronic probes can detect temperature, voltage, light intensity, sound, distance, dissolved oxygen, or pH while the computer digitally records and graphs the data. Students can observe graphs being produced as an experiment is being conducted, and they can obtain immediate graphs and see trends. This allows them to focus on the concepts they are exploring, spend more time analyzing their results, and ask new questions.

*Computer simulations.* The use of simulation programs support students in their understanding of experiences that may be difficult to create in the classroom environment. Computer simulations allow students to explore and manipulate ideas in artificial environments that minimize extraneous details and make it easier to study interactions among variables. Simulation experiences are an example of replication of what is used in the outside world. Astronauts are trained in space travel using simulation programs. Scientists often use simulations to investigate the inner workings of the human body. When is a simulation valid and when is the actual hands-on experiment necessary? Veterinarian students in a university setting posed this question. In some cases it is important to experience the lab dissection of the frog or other animal, but in other cases the animated simulation allows students to understand the workings of muscles and tendons supporting the extension of the human body through physical exertion. In some cases the ethical and moral questions are raised about the use of live animals when a simulation can replicate the experiment and understanding in the same way.

Model-building programs. Computer model-building programs allow students to visualize and form mental models of abstract concepts. The teacher helps students move from a hands-on experience in the lab to the computer program and back again, encouraging them to see the relations between concrete objects they are manipulating and abstract computer programs. An example model-building program is one that allows students to "see" density. Students choose from different kinds of materials of various densities to build objects of different sizes. Density is shown on the screen by the number of dots per square inch.

Internet. Online technologies can support restructured learning environments through network connections. Existing classroom computers can be linked to cameras and cables connecting them with remote stations through the Internet and/or dedicated phone lines. Teachers are no longer the sole experts as students can access information from outside experts and collaborate with peers from distant geographic locations (Hayden, 1999). These connections can support a video broadcast or a threaded discussion from opposite sides of the earth. These conversations can lead to better understanding and support the acquisition of knowledge. Students can take virtual field trips and explore science events as they happen. At the NASA website, students engage in live web casts introducing astrobiologists' fieldwork study of microbial mats. Students then interact with active astrobiologists in a forum as they compare and contrast their own investigation methods with those of scientists studying microbial mats in Baja, California. Students conclude with a third follow-up web cast on the results and conclusions of both investigations. (http://quest.arc.nasa.gov/projects/astrobiology/fieldwork/index.html)

Telecommunications networking. Students can communicate with scientists who are working in specific fields. Teachers can contact scientists and engineers in at local institutions, or they can arrange for the collaborations through the many projects designed to set up partnerships. In San Diego, the San Diego Science Alliance (http://www.sdsa.org/) has a database of scientists and engineers who work with K-12 students and teachers to assist in improved science education for all.

Portable keyboards and palm pilots. New technologies are often small and portable allowing their use during field trips, labs and from home to school. Eighty percent of what students use computers for in the classroom is writing. Portable keyboards can be an economic supplement to computers. They can be used for writing and brainstorming and then connected to the computer for transfer of files to more sophisticated software programs for multimedia and desktop publishing.

### Integrating Science, Writing and Technology

We have provided numerous ways to integrate science and writing, as well as science and technology. All of the methods for writing in science class can be enhanced by use of computer technology. In addition, the examples in the previous section on ways to infuse technology into science teaching and learning involve writing. Many of the examples for using technology in science class involve students accessing and then using information; the ways in which they use and process the information all involve writing.

Research has shown that students write more when using computers, as compared to writing with pen and paper (or word processing equipment, including typewriters). They enjoy their writing more and are more motivated to write when using technology. Teachers report that writing has always been a difficult process for students; many young people balk when asked to revise and re-do because it has been such a cumbersome process. However, technology opens up a whole new and positive experience for students as they learn and practice writing. They don't mind editing if they can do it on the computer. It is easier to visualize the whole paper on a computer, easier to play with ideas, and easier to edit on the computer.

Students think about their writing much more when they write on the computer. This is especially true in telecommunications. Even when using email, students consider their spelling, punctuation and grammar. They pay more attention to what they write and how they write because they are concerned with the impression they make with the people that read their writing. Writing becomes important because it represents them. When participating in threaded discussions, young people know that a variety of people will be reading what they write and they care about what the readers think of them. They want to make a positive impression and, thus, they do their best in their writing.

The future of technology is hard to predict, but it is clear that it will continue to change the way students learn and share information. Science and writing are both areas of our school curriculum that have taken full advantage of the benefits of technology. The typewriter evolved into the word processor and desktop publisher. The science laboratory has become digital and students' natural interest in technology and creativity has led to enhanced experiences reflecting the real world of scientific discovery. Wireless technology has started to become familiar at school sites and, as it becomes commonplace, will open up whole new avenues for teaching and learning. What we must do is make sure that all students are able to benefit from these technologies and have an equal opportunity to benefit from the integration into K-12 classrooms. Working with teachers to develop model projects will assist in this transition.

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