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ABSTRACT

Many believe that technology offers the most benefit to students and teachers when it is integrated into the core curriculum rather than being taught as a separate discipline. This publication is intended to assist teachers in incorporating technology into learning activities in mathematics and science. Chapters emphasize issues concerning mathematics and science education standards, teaching and learning with technology, ensuring equity, common instructional technology, succeeding with minimal resources, and changing classroom roles. Included is a list of resources, web sites, and organizations. (Contains 56 references.) (ASK)

Integrating Technology into Middle School Mathematics

It's Just Good Teaching

Northwest Regional Educational Laboratory

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Denise Jarrett—Research, writing, photography
Kit Peixotto—Conceptual support and guidance
Denise Crabtree—Design and production
Lee Sherman—Editorial review
Samantha Moores—Proofreading
The Richard H. Hungerford School, Staten Island, NY—photo on page 23

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Integrating Technology into Middle School Mathematics

It's Just Good Teaching

by Denise Jarrett

A publication by the NWREL Mathematics and Science Education Center
in cooperation with the NWREL Technology Center's Northwest Educational
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Northwest Regional Educational Laboratory

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Preface

Technology touches our lives daily and is recognized as a necessary component for success in the 21st century. While students are often adept at using computers, the full potential of the myriad available technologies remains untapped in many educational settings. In mathematics and science, graphing calculators, the Internet, spreadsheets, and other technology tools can engage students in authentic learning opportunities that enhance the development of higher-order and basic skills.

Many believe that technology offers the most benefits to students and teachers when it is integrated into the core curriculum, rather than being taught as a separate discipline. In mathematics and science teaching, there are a variety of avenues for incorporating technology into learning activities. We offer this publication to assist teachers in this effort. *Integrating Technology into Middle School Mathematics* continues the Northwest Regional Educational Laboratory's series entitled, *It's Just Good Teaching.* This document follows a similar format established by previous publications in the series, including a review of the current literature and research, a variety of illustrative "real-life" examples from Northwest classrooms, and an extensive listing of available resources.

Readers will also recognize some important departures from the previously established approach. Perhaps most significant is this document's focus on middle school mathematics teachers and their classrooms. Previous publications in this series address all K-12 mathematics and science educators. In this document, the pedagogical considerations of middle school teaching and the content area of mathematics frame all of the examples. Nevertheless, many of these examples portray technology's role in integrated mathematics and science curricula. We are confident, therefore, that teachers outside of middle school mathematics will find many useful ideas and resources within these pages. We invite readers to read the publication from front to back, or to use it as a resource guide, selecting those areas that are of immediate interest.

The effective use of technology in education poses opportunities and challenges for today's classroom teachers. National standards in mathematics and science call for knowledge and skills that are often directly addressed when technology becomes an integral element in teachers' repertoire of instructional strategies. We believe technology is a critical ingredient in efforts to provide all students with a quality mathematics and science education that will prepare them to succeed.

Kit Peixotto
Director
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Technology Center

Introduction

As industrialized nations move from their resource-based economies to information-based systems, new demands are placed on citizens. Basic skills in reading and arithmetic are no longer sufficient. Increasingly, jobs are going to employees who have communication, problem-solving, mathematical, and technological skills to aid them in analyzing large quantities of often conflicting information (National Council of Teachers of Mathematics [NCTM], 1989; American Association for the Advancement of Science [AAAS], 1990).

Advances in information technology have expanded the personal and professional horizons of those who can afford to have access to the technology, writes Michael Milone (1996).

"Information is the new capital and the new material, and communication is the new means of production."

—National Council of Teachers of Mathematics (1989), *Curriculum and Evaluation Standards for School Mathematics*

"Through computer networks, people share ideas, opinions, and information in a way that was never possible before," he states. "They gain access to extraordinary resources that can facilitate their hobbies, involvement in and knowledge of politics, participation in chat groups, and finding a job. Access to the information superhighway is quickly becoming an essential element for full participation in contemporary society."

Many educators, parents, and policymakers agree. They are eager for students to master information technologies. To prepare students, many teachers are working hard to integrate technology into their instruction despite the familiar limits of time and resources. The effort is worthwhile, they say, not only because technology can equip students with job skills, but because technology can facilitate learning.

When technology is integrated into the core curriculum in service of standards-based instructional strategies, it can be an exceptionally powerful teaching and learning tool. According to today's standards for mathematics education, problem solving, communication, and mathematical thinking are the overarching skills required by modern life. Technology can provide the tools for applying these skills (NCTM, 1989; AAAS, 1990, 1997; National Research Council [NRC], 1996).

The interactive nature of technology can also empower students to develop such personal strengths as initiative, problem solving, and persistence. Even in high-technology professions, qualities such as, "creative habits of mind, the ability to look at things in a multitude of different ways, (and) to respond effectively to novel and unexpected developments" are valued as keenly as technical expertise (Brundish, 1998). Today's high-tech companies are avidly recruiting employees with these traits, as well as those with talents in storytelling, graphic arts, and music (Kotkin, 1997).

As information technology is subsumed into the greater culture, it becomes more transparent, viewed simply as an implement to foster human achievement and communication. Technology in the classroom should play a similar role: as an everyday tool that empowers students to explore and master important ideas and to develop valuable personal traits.

Mathematics and science education standards

Over the past decade, education standards in mathematics and science have been developed in response to wide concern about student achievement and the demands of an increasingly scientific, mathematical, and technical world. Advances in information technology have made it possible—even necessary—for students to access mathematical and scientific concepts in greater depth and with more sophistication than ever before. Technologies such as graphing calculators, geometric construction software, multimedia tools, and the Internet are tools that can enhance students' abilities to actively construct their own knowledge—an important element in today's education standards.

In 1989, the National Council of Teachers of Mathematics identified teaching and learning standards to ensure that students learn the mathematical and technical skills necessary to participate in today's society (NCTM, 1989, 1991). Later, the professional science community published its views on what constitutes literacy in science, mathematics, and technology in the publication, *Science for All Americans: Project 2061* (AAAS, 1990). The National Research Council outlined its vision of science education in the publication, *National Science Education Standards* (NRC, 1996). In 1995, the National Middle School Association upheld many of the same teaching standards put forth by the mathematics and science community in its position paper, *This We Believe*.

National test scores in the United States indicate that student achievement in mathematics is improving at all grade levels (Reese, Miller, Mazzeo, & Dossey, 1997). However, according an international study, U.S. students underachieve in regular and advanced mathematics compared to their international peers (Beaton et al., 1996; Mullis et al., 1997, 1998).

In 1996, the Third International Mathematics and Science Study (TIMSS)—the largest and most comprehensive comparative international study of education in history—began publishing the results of its research. TIMSS reports that U.S. students in eighth and 12th grades are significantly behind their counterparts in other parts of the world in such areas as proportionality, measurement, and geometry, as well as some areas of algebra and advanced mathematics, such as calculus. From the study's data and an extensive analysis of textbooks and curriculum, TIMSS researchers concluded that mathematics learning in U.S. classrooms too often focuses on memorizing facts and formulas, and the typical mathematics curriculum is too broad and repetitive (Beaton et al., 1996; Mullis et al., 1997, 1998).

Changes in what and how mathematics should be taught will be the basis for extensive thought and analysis in the coming decade in light of technological advances. Perhaps never before has mathematics education entered such uncharted waters ....

—Thomas Cooney (1990)
Teaching and Learning Mathematics in the 1990s

The study also revealed what many proponents of education reform have been saying for quite some time: Young people learn best when actively engaged in the learning of meaningful mathematical concepts and facts, rather than simply memorizing formulas. Many educators believe that technology can play an important role in this kind of active-learning, standards-based education. They believe that technology can enhance students' access to and understanding of important mathematical and scientific concepts and create learning environments that help students develop problem-solving and communication skills (NCTM, 1989, 1991; NRC, 1996; AAAS, 1990).

Technology in the middle grades

Middle-grade mathematics teachers know that this is an especially critical time for developing the mathematical curiosity and skill of all of their students. Because this is when many students are first grouped by their ability—a placement that often follows them through high school—teachers want to do their utmost to help students achieve (Branca, Breedlove, & King, 1992).

But early adolescence is a time of tremendous physical, emotional, and intellectual change. For middle-grade students, academic success is frequently dependent upon many of their developmental needs being met. These developmental changes occur irregularly among adolescents, therefore, a middle-grade classroom is likely to have students with wide-ranging individual differences (National Middle School Association [NMSA], 1995). This poses a challenge for the middle-grade teacher who strives to respond to the developmental and learning needs of his students.

One of the most significant intellectual developments for young adolescents is an emerging ability to think abstractly. These children have "a growing capacity for conceptualization, for considering more than a single idea at a time, and for planning steps to carry out their own learning" (NMSA, 1995). Thus, they are ready to learn how to think creatively and to solve problems. However, most middle-grade students need continuing concrete and experiential learning while they develop their conceptual powers (NMSA, 1995).

Today's technology can offer adolescents a bridge from concrete to abstract thinking, enabling them to observe and create multiple representations of mathematical ideas: numerically, graphically, and symbolically. For example, students can use geometric construction software to investigate the relationship between the circumference and diameter of a circle. They can measure several round objects and record the circumference and diameter (numerical representation). They can plot the values and estimate a "best fit" (graphical representation). Students can then determine the best fit equation (symbolic representation).

Technology can also help teachers respond to students' diverse learning styles by creating rich environments that engage students' tactile, visual, and auditory senses. Finally, information technologies such as word processing, calculators, spreadsheet tools, and the Internet can enable middle-grade students to begin learning higher communication and problem-solving skills—abilities that are essential to mathematical thinking (NCTM, 1989).

Teaching and learning with technology

There is some public debate about technology's ability to enhance learning. Some people argue that educational technology has yet to improve students' achievement on standardized tests (Oppenheimer, 1997; Bronner, 1997; Mendels, 1997). Others state that standardized tests are the wrong tool to measure the efficacy of technology on learning. These tests usually target basic skills and recall of facts, they say, while technology's greatest impact on learning is in the area of problem solving and higher-order thinking. Even when standardized tests are modified in an attempt to measure depth of understanding and problem solving, the format usually does not lend itself to an accurate assessment of higher-order thinking (U.S. Congress, Office of Technology Assessment, 1995; Valdez & McNabb, 1997). This dilemma can influence how mathematics is taught, especially in the middle grades.

"Math is the biggest area where teachers are hesitant to use technology," says Darla Jones, technology coordinator for Romig Middle School in Anchorage, Alaska. "We're supposed to prepare students to be better thinkers and problem solvers—that's what employers keep telling us—and technology can enhance these skills. But, because of the importance of standardized test scores, teachers feel a big pressure to get through the book rather than spend time on technology-based projects that develop higher-order thinking. Until the public understands that standardized tests really aren't the best way of measuring intelligence, we're in a double bind."

Nevertheless, there is evidence that technology can improve students' computation and writing skills, problem-solving and inquiry strategies, as well as cooperative learning, motivation, and self-esteem (U.S. Congress, Office of Technology Assessment, 1995; Valdez & McNabb, 1997; Means & Olson, 1997; Knapp & Glenn, 1996; Sandholtz, Ringstaff, & Dwyer, 1997). This evidence has persuaded many teachers, like Jones, to embrace technology in their teaching. After several years teaching in the classroom, Jones earned a master's degree in educational technology from Johns Hopkins University in Baltimore, Maryland, and became technology coordinator for Romig so that she could help other teachers maximize technology's potential in the classroom.

"Computers are becoming such a daily part of every person's life, so it's making less and less sense for us to teach the way we've always taught," says Jones. "I think the teaching profession is reaching a point where we're just going to have to deal with that."

Getting started. There is little doubt that learning to teach effectively with technology requires a significant commitment by the teacher. Some researchers estimate that it takes about five years of using instructional technology before teachers feel proficient (Mandinach & Cline, 1994). To avoid feeling overwhelmed, teachers will want to integrate technology into their teaching in small steps, says Louis Nadelson, physics teacher at Capital High School in Olympia, Washington, and a frequent writer on using technology in mathematics and science teaching.

"Teachers need to set an attainable goal," he advises. "They will want to structure

activities that aren't too complex and involve one technology tool, such as a spreadsheet or Internet search. Each small success will build teachers' confidence, and every year they can add more advanced activities."

For example, a teacher might begin using technology in her teaching by joining her students in an exploration of the Internet. Most libraries and book stores carry a variety of books on how to use the Internet, and there are a number of online guidelines available, such as *Internet Basics*, published by the Northwest Educational Technology Consortium (http://www.netc.org/basics/). Using the guidelines, the teacher and students can learn together how to formulate online searches and to analyze search results, says Nadelson.

The teacher can suggest that each student find three Internet sites that support student learning in mathematics —such as an interactive mathematics activity, a math dictionary, or an organization supporting mathematics education. Later, everyone can share their discoveries and discuss the merits of each Web site. The teacher might suggest that students participate in an online activity, perhaps a problem-of-the-week sponsored by such organizations as the Math Forum (http://forum.swarthmore.edu/midpow/) or MathCounts (http://thechalkboard.com/MC/Problems/problems.html).

When she is ready, the teacher can add a spreadsheet-based activity to her mathematics curriculum. Her goal might be to engage students in three activities involving computer spreadsheets. For example, the teacher can introduce students to the use of spreadsheets to calculate, analyze, and present quantitative data. After creating a spreadsheet template, the teacher can ask students to estimate the length of their arms or the circumference of their wrists and then enter this data into the spreadsheet. Students can then make actual measurements and enter this data into the spreadsheet as well.

With both sets of data in the spreadsheet, students can look for patterns or relationships in such things as the ratio of wrist circumference to arm length, or the accuracy of their estimates of each measurement. Working together, students can also decide how best to display their data (i.e., pie, line, or bar graphs) and discuss the advantages and disadvantages of each kind of display for each data set (for instance, pie graphs can display only one variable).

In another spreadsheet activity, students can enter the estimated heights and weights of various dinosaurs, as well as their diets and habitats. By linking the computer to a projector or large monitor, the teacher and students can view the spreadsheet data together, perhaps comparing the mean, median, and mode of the dinosaurs' measurements. As they analyze the data, they can look for relationships in the body size of the meat-eating dinosaurs versus the plant eaters.

The early stages of technology implementation can be challenging for teachers. They must learn to solve technical problems. They often must adapt or design technology-based curriculum and materials that will enhance their students' learning of important mathematical concepts. Also, technology-based instruction often places demands on teachers' content knowledge as students engage in interactive learning experiences that are more student-directed.

"Learners working with effectively integrated technologies can discover the wonders of the universe and capture those wonders to aid them in both personal and professional growth."

—William C. Kyle Jr. (1997)
Journal of Research in Science Teaching

Nevertheless, many teachers decide to begin incorporating technology into their instruction because they believe the benefits make the effort worthwhile. As their experience with technology grows, teachers often report feeling an increased sense of effectiveness and professionalism (Means & Olson, 1997; Knapp & Glenn, 1996). The key is to approach the challenge one step at a time, with patience and persistence.

Buckets of data: Aquatic creepers and crawlers

The Freewater School is old. It first opened its doors in 1912, the same year the Titanic struck an iceberg and women won the right to vote in Oregon. Another event was the birth of Alan Turing, a British cryptographer who developed the theory of a "thinking" machine, laying a foundation for today's computer. This last small coincidence takes on meaning today as this rural eastern Oregon school steps from its agrarian history into the information age.

Freewater School is located in Milton-Freewater, a town of 5,300 souls that is surrounded by purposeful rows of apple and cherry trees. The three-story brick building serves grades three through five with a student population that is 40 percent Latino and 60 percent White. According to the Oregon Economic Development Department, half of the city's adult residents earn low to moderate incomes, primarily from seasonal jobs in agriculture, food processing, and timber production. At Freewater School, 60 percent of the children receive free or reduced-price lunches. These facts influenced recent changes at the 86-year-old school.

Teacher Jim Huff is embracing these changes. To get to Huff's fifth-grade classroom, you must climb three flights of wide stairs. Footfalls echo up to the high ceiling. Outside his classroom, Grandma Mary tutors a student in multiplication tables. Inside, Huff stands at an overhead projector, reviewing a mathematics worksheet with his 28 students, who are all vying for his attention. Around the room, several decades of architecture and educational paraphernalia coexist in a friendly jumble. The doorknobs are bulbous with keyholes big enough for peeping. Retired textbooks line the bookshelves, and pinewood tables bear dusty computers from the large-floppy-disk years. However, parked expectantly in a corner is an assemblage of '90s technology.

Huff is one of five teachers at Freewater who are lead teachers in the use of educational technology. The school received Internet access and five multimedia mobile units in 1997 when the Milton-Freewater School District obtained a $200,000 grant from the Oregon Technology Literacy Challenge Fund. Awards are based, in part, on a school's level of poverty. The district used the funds to equip each of its five schools with multimedia equipment and a set of 25 eMates, rugged portable

computers that can be taken just about anywhere. Each mobile cart contains a Macintosh 8600 computer, a printer and scanner, a large-screen television, digital and video cameras, and a FlexCam (a flexible camera attachment for desktop computers, distributed by VideoLabs, Inc.). This year, students and teachers are learning to search the Internet and work with such interactive software as HyperStudio, ClarisWorks, and Kid Pix Studio.

"I'm just an emerging technology teacher," explains Huff during a break. "At Freewater, we're just now getting our feet wet, and a lot of teachers are hesitant. I was, too. I kept thinking that it would all go away, but I realized that the sooner I started learning how to use it, the quicker I'd get on the boat. Technology is going to be one of the greatest tools in education—and that's a big statement from a nontech person like me."

This spring, Huff and his students are preparing to take a field trip to the banks of the Walla Walla River as part of a water ecosystem project. At the river, students will gather data on water organisms and record the data in a spreadsheet on their portable computers. Later, they will report their findings in oral and multimedia presentations. After the morning's mathematics review, Huff and his students, bearing eMates and buckets, climb aboard a school bus and head for the river.

From the highway, the yellow bus pulls onto a dusty path and wends past green paddocks. It soon turns onto an open field of grass and bumps to a stop near the tree-lined bank of the Walla Walla.

Youngsters clamber off the bus with high anticipation.

The day before, Huff arranged the site into four stations with worktables and benches. Today, he places students in small groups, and they rotate from place to place. At three stations, staff members from the Oregon Department of Fish and Wildlife and the Walla Walla Watershed Council talk with students about the life cycle of fish, riparian restoration, and water quality. Students clamor for answers: Why does the river run so fast? Where does it go? Where do fish sleep?

At one station, students exchange their sneakers for rubber boots and gather up buckets and nets. Leading the way along a cow path thick with bramble, Huff guides his gaggle of preteens to the water's edge. There, students wade into a shallow rush of water, dipping nets into eddies to collect samples of the river's residents: mayfly nymphs, the wiggly larvae of midges, and a fingerling or two. A parent volunteer busily snaps photographs of the action with a digital camera.

Carrying their treasures to higher ground, students peer and poke into their buckets. "Oo, what the heck is that?" exclaims Russ, scrutinizing a mosquito larva. Students compare their organisms to an illustrated key of aquatic insects, counting how many of each organism they have collected and writing their data on a worksheet. Then, sitting down in the grass or standing at the makeshift tables, they enter their data into a spreadsheet on their portable computers. Soon, everyone has been through all four stations, and the students board the school bus for the return ride.

The next day, students use their portable computers to create tables or pie charts based on their data, creating a graphic representation of the river's population of tiny inhabitants. Working in pairs, the students peer intently at the screens of their eMates. While one student operates the keyboard and stylus, the other dictates information. Together, they decide how they want to display their data. Luisa and Emillio decide on a pie chart. After printing their chart, they study it and determine that the lobsterlike nymph of the stonefly accounts for about a third of their sampling. They then hypothesize that this measurement might accurately represent the ratio of stonefly to other small organisms in the river.

Luisa and Emillio and their classmates use word-processing programs on the portable computers to write short reports about their river investigations and their analyses of the data they collected. While the students are writing, Huff links the digital camera to the Macintosh 8600 and downloads the digitized photographs from the field trip, then sends the file to a color printer. The students will incorporate these color photocopies into their oral and multimedia presentations.

But first, they have to write their reports, a task made easier and more fun with the portable computers. Says Heather: "I love them. You can draw and print stories on them, and send messages, and you can take them with you on field trips. Sometimes when you're on a field trip, if you don't have something to write on, you forget important details."

Her partner, Jeremy, agrees. "They're neat. They're not big and bulky like the (desktop) computer, and you can do a lot of things with them, like put spiders all over the screen," he says, displaying a page covered in creepy clip art.

The age of information technology has arrived at Ferndale School, but some things will never change.

Below is an overview of some of the ways in which technology can be particularly effective, such as enhancing students' motivation and problem-solving skills, and enriching the mathematics curriculum. The technology that is referred to here is explored more fully in the section "Common Instructional Technology" on page 24, which offers brief examples of how these tools can be used in teaching.

Increasing student motivation. Even hesitant students can be stirred to enthusiasm when given an opportunity to work on a computer or calculator. This seems to be true for students who've shown less initiative or proficiency with traditional schoolwork. Teachers report that technology can enhance student motivation in the following ways (Means & Olson, 1997):

- Even quiet or reticent students can become "stars" with technology
- Students are more willing to write and work on computational skills
- Students appreciate the immediate feedback provided by the computer
- Students gain a sense of accomplishment and power when working with technology
- Students feel more competent and are proud of their technological skills
- Students demonstrate their knowledge more effectively when they have multiple ways of communicating their understanding

Many students find the interactive environment of technology exciting. When students research information sources on the Internet, engage in educational

electronic games, or construct presentations incorporating text, sound, animation, and hyperlinks, they are working in an interactive environment. This environment often stimulates students to explore an idea more deeply and to present their knowledge more effectively (Knapp & Glenn, 1996).

Developing communication skills. "Middle school students should have many opportunities to use language to communicate their mathematical ideas," state the NCTM standards (1989). Multimedia tools, the Internet, word processing, and the text functions in spreadsheet and calculator tools can help students develop important communication skills. The text capabilities of these technological tools enable students to more easily proof and edit their work than when composing with pencil and paper. They can create more professional-looking documents, inserting graphical images and design elements to illustrate and clarify their ideas.

The text windows in many spreadsheet and calculator tools enable students to use words to clarify their mathematical thinking and to enhance their graphs, tables, or geometric constructions. This not only aids students, it provides a valuable opportunity for teachers to gain insight into their students' thinking processes and to identify misconceptions.

Multimedia tools provide students with multiple means for expressing themselves. They can combine text with music or other sounds. They can create a "slide show" of pictures or drawings to express a concept visually. They can integrate video or animation into their presentations. They can also create their own design elements using borders, symbols, and shapes to enhance the clarity and aesthetic quality of their work. For example, students can create "math autobiographies" in which they include a written journal (expressing their thinking process or noting what they're having difficulty understanding), copies of their work, and even photographs of classroom presentations.

With access to the Internet, students can step beyond classroom walls and enter into global discourse. They can share ideas with other youths at distant locations, collaborate with them on projects, compete with them in games, or exchange information. Also, students can converse with adult professionals who are willing to act as mentors, professional contacts, or distance-learning instructors. With the Internet, students can communicate with numerous sources: their peers as well as adult professionals.

Developing problem-solving skills. Problem solving is an essential skill that students should develop, say mathematics education leaders (NCTM, 1989). Placing problem solving at the center of mathematics learning will help students develop reasoning skills that will serve them over a lifetime of learning, creating, exploring, and adapting to change (NCTM, 1989). Furthermore, students need to learn to use calculators and computers to help them apply mathematical ideas to problem situations (NCTM, 1989; Knapp & Glenn, 1996).

Technologies such as calculator and graphing tools, databases and spreadsheets, and geometric construction tools are designed to help people solve problems. Allen D. Glenn, dean of the College of Education at University of Washington in Seattle, and researcher Linda Roehrig Knapp (1996) are the authors of *Restructuring Schools With Technology*. They state that these technologies allow teachers to incorporate problem solving in their curriculum in unprecedented ways.

With calculators, students can focus on developing strategies for solving complex problems, rather than laboring over computations. Databases and spreadsheets enable students to analyze and interpret large amounts of data and information, often empowering them to explore important mathematical content not accessible without the aid of this technology, state Knapp and Glenn. Geometric construction tools allow students to develop formulas and gain a deeper understanding of mathematical functions without tediously measuring and constructing geometric figures.

During the process of operating a computer or calculator, a student will need to problem solve. Selecting appropriate software and troubleshooting when the application doesn't respond as expected are common "problems" that must be solved when using technology. On a graphing calculator, for example, a student might need to figure out why she or he obtained a dubious-looking graph. These situations can be important learning experiences. Knapp and Glenn argue that resolving these kinds of challenges teaches valuable qualities such as persistence, curiosity, and reasoning.

Building basic skills. Tutorial technology typically directs students through set procedures that lead to predetermined results, such as many educational computer "games." While this kind of technology is unlikely to facilitate inquiry-based learning or problem solving, it can be effective for practice and remedial work on mathematical computations and algorithms.

Tutorial technology that engages students' visual and auditory senses can make practice fun. Some students respond favorably because they can work independently and at their own pace. Students often appreciate being able to make their mistakes in private and receive immediate and nonjudgmental feedback from the computer, say Knapp and Glenn.

However, teachers will want to be certain to use tutorial technology in ways that don't exacerbate gaps between high- and low-achieving students (AAAS, 1997). Basic skill-building should be linked to more complex concepts in the core curriculum. If students master basic skills in isolation from the rest of the class' learning of the core curriculum, they are frequently unable to apply those skills to realistic situations, state Knapp and Glenn. Therefore, tutorial technologies should be physically located in the classroom whenever possible. This enables teachers to more effectively integrate skill-building into students' core learning experiences. Also, teachers will want to choose tutorial programs that permit students to practice mathematical skills in problem-solving contexts.

Natachia Sinkfield teaches eighth-grade mathematics at Fred Nelson Middle School in Renton, Washington. Her students practice entrepreneurial skills using the tutorial software, Hot Dog Stand, and explore geometric relationships using Geometric superSupposer (both are products of Sunburst Communications). Sinkfield has found that her students need access to both tutorial software and programs that engage them in higher-order thinking. Students can gain much-needed confidence by mastering basic skills while using the colorful and interactive tutorial programs, she says.

"It's good for students to be able to say, 'Oh, this is easy!', or 'Look, Mrs. Sinkfield, look what level I got to,'" she says.

Creating authentic learning experiences. Unlike tutorial technologies, which often contain preset content that might not match the goals of the teacher, generic technologies such as spreadsheet, graphing, and multimedia tools; the Internet; and word processing can support any curriculum (Knapp & Glenn, 1996). These technologies can be assimilated into a teacher's core teaching practice (Means & Olson, 1997).

Generic technology can be used to engage students in authentic learning experiences. Authentic tasks are those in which students are actively engaged in challenging work with real-world connections (Means & Olson, 1997). For example, students are making authentic uses of technology when they use it in the same way, and for similar purposes, as adults do in the workplace—to communicate and obtain information (Means & Olson, 1997).

According to Means and Olson, the following are features of authentic uses of technology:

- The technology supports student performance of complex tasks that are similar to those performed by adult professionals and/or fill a genuine need of the student.

- The technology is integrated into activities that are a core part of the classroom curriculum.

- Technology is treated as a tool to help accomplish complex tasks (rather than as a subject of study for its own sake) that engage students in extended and cooperative learning experiences that involve multiple disciplines.

Enriching the curriculum. Technology empowers students to explore beyond traditional mathematical content. Calculator and spreadsheet tools can create opportunities for students to manipulate and interpret large quantities of data without getting bogged down with time-consuming computations. This allows teachers to enrich the middle-grade mathematics curriculum by including the increasingly important areas of statistics and probability, data representation and analysis, as well as other complex mathematical ideas that require creative problem solving (NCTM, 1989).

Students still need to learn algorithms and be proficient with some paper-and-pencil computation, but calculators and computers should be used for complex calculations, such as long division and many iterative calculations. With calculators and computers to do some of the repetitive computations, students are more free to explore higher mathematical ideas in algebra, geometry, and probability (NCTM, 1989).

Rachel Nosek teaches mathematics and science at Romig Middle School in Anchorage, Alaska. Nosek's seventh- and eighth-grade students are engaging in an extended interdisciplinary project on oceanography. Part of the project involves building a three-dimensional model of a section of the Pacific Ocean floor. To determine an appropriate scale for their model, students need to convert numerous scale measurements from a bathymetric map (a topographical map of the ocean floor). Nosek's students program a computer spreadsheet to do the conversions.

"I'm not going to expect students to hand-crunch 50 numbers, that's cruel and a waste of everybody's time," says Nosek. "But after they've demonstrated to me on paper that they understand the concept of ratios and can do the conversions, then I believe they should use the computer to manipulate the data. Students still have to understand the concept of ratio to be able to write the formula for the computer spreadsheet. But without a rapid way of manipulating the data, we couldn't do this project."

The new technology not only has made calculations and graphing easier, it has changed the very nature of the problems important to mathematics and the methods mathematicians use to investigate them. Because technology is changing mathematics and its uses, we believe that—

- Appropriate calculators should be available to all students at all times
- A computer should be available in every classroom for demonstration purposes
- Every student should have access to a computer for individual and group work
- Students should learn to use the computer as a tool for processing information and performing calculations to investigate and solve problems

—National Council of Teachers of Mathematics (1989)
Curriculum and Evaluation Standards for School Mathematics

Technology also permits teachers to spend more time on the concepts of scaling, numerical analysis, error, and translating across representations—areas of mathematics that are increasingly important in business, industry, and science, say Demana and Waits (1990). With technology, students can generate multiple representations of problems. They can analyze and solve word problems graphically, a process that bolsters students' confidence and problem-solving abilities, they say.

"The power of visualization helps students question, conjecture, and discover important mathematical concepts," state Demana and Waits. This gives students with diverse learning styles multiple opportunities to connect with the concepts they are learning.

Addressing multiple intelligences. Some experts contend that people store information in long-term memory in three ways: verbally, visually, and a combination of both (Moore, Myers, & Burton, 1994). In the traditional classroom, in which lecture and reading from a textbook are the primary modes of learning, students store newly acquired knowledge largely in "verbal strings." However, verbal strings are usually more difficult to recall. In the learning process, people often find it easier to retrieve information that has been stored both verbally and visually (Moore et al., 1994). Technology's interactive qualities can engage students' verbal and visual senses, as well as their tactile sense and imagination, increasing the likelihood that they will store what they learn in long-term memory.

In his book, *Frames of Mind*, educator and writer Howard Gardner (1983) develops a theory about the various ways in which people learn that he calls "multiple intelligences." Gardner suggests that every person has seven or more intelligences—including logical/mathematical, linguistic, and spatial/visual—and each person will have a particular ability and weakness in one or more of those intelligences. From a teacher's point of view, students' multiple intelligences means multiple opportunities for them to succeed in the classroom. Access to technology can empower students to make the most of their individual aptitudes (Dickinson, 1994).

Ensuring equity

Despite growing evidence that technology can enhance learning for all students, "technology and equity are not inevitable partners" (Neuman, 1991). Access to technology, as well as issues of use and gender, can significantly influence the effectiveness of technology on learning (Neuman, 1991; President's Committee of Advisors on Science and Technology, Panel on Educational Technology, 1997; Tarlin, 1997; Miller, Chaika, & Groppe, 1996; Zehr, 1998; Means & Olson, 1997; Sutton, 1990).

> "Society can no longer afford to have large segments of its population isolated from the technological advantages that many enjoy."
>
> —William C. Kyle Jr. (1997)
> *Journal of Research in Science Teaching*

Access to technology. According to a report by the Panel on Educational Technology, the two most common measures of equitable access to technology are the ratio of computers to students and the number of hours students spend on computers (President's Committee, 1997). However, the report also notes that the degree of equity achieved is frequently determined by the modes in which the technology is used, rather than by the number of computers or number of hours spent using them. Studies indicate that some students have opportunities to participate in higher-order learning and problem-solving activities while others are restricted to using technology primarily for basic skill-building. According to the report, these differences in technology usage are often related to socioeconomic factors and can be as problematic as having inadequate resources.

The report states that schools in poorer and wealthier communities have about the same number of computers per student. Nevertheless, students from poorer schools are more likely to be taught *about* computers than to use computers for learning of the core curriculum. They are more likely to use computers for drill and skill building than students from affluent schools, who are 25 percent more likely to use computers for higher-order thinking tasks.

Significant differences also persist in the availability of computers in students' homes. The report notes that 14 percent of students from poorer families have computers at home, while 73 percent of students from affluent homes do. This gap is also evident between ethnic groups. In 1993, African Americans and Latinos were nearly 60 percent less likely to have a computer at home than Whites. This has serious implications for many of this country's children. As the role of technology grows in the classroom, children with computers at home will have an increasing advantage over children who do not.

"The primary issue of concern is how to ensure that in the process of creating the future we don't create two cultures: the technological haves and the have-nots," writes William C. Kyle Jr. (1997) in the *Journal of Research in Science Teaching.* "How do we ensure that the power of technology, the fact that it can both provide and equalize access to information, is realized among all citizens?"

This is a question that all teachers will want to keep uppermost in their minds as they integrate technology into their teaching. Whether working in a technology-rich environment or with limited resources, teachers can take deliberate steps to ensure that all of their students gain equal access to available technology. Further, teachers can make certain that students use the technology in ways that maximize their potential for learning of both basic skills and complex tasks.

Enhancing achievement. The Panel on Educational Technology reports that technology can be especially valuable to lower-achieving students. An analysis of multiple studies examining instructional uses of word processing, for example, found that 27 percent of students overall improved in the quality of their writing, while studies of remedial programs found that nearly 50 percent of the students improved with the use of technology. In mathematics, one computer-based program for educationally disadvantaged students recorded a 90 percent average performance improvement—far higher than the gains typically realized by high-achieving students.

While higher achievers are more frequently allowed to use computers in the performance of complex and authentic tasks, lower-achieving students are more likely to be assigned to extensive drill and practice on isolated basic skills. According to the panel's report, this is often due to a belief that students must master basic skills before they can perform higher-level thinking and problem solving. However, many researchers now believe that learning is most effective for both higher- and lower-achieving students when they acquire basic skills in the course of undertaking more complex, real-world tasks.

Strategies to engage all students

- Invite professional scientists and mathematicians who use technology in their work to speak to your class; be sure to invite individuals who represent a diversity of ethnic and cultural backgrounds, both sexes, and all forms of physical abilities
- Ensure that all students get equal time at the computer, doing work that includes complex tasks, not just drill and practice
- Ask technical questions of all students, not just those who are technology savvy
- Assign targeted groups extra duties, such as turning the computer on before class and previewing software
- Have students examine software for bias as a class activity

—Barbara Warren-Sams (1997)
Closing the Equity Gap in Technology Access and Use

Gender differences. Teachers will also want to ensure that a technology gap doesn't occur between boys and girls. A gender gap commonly occurs around fifth grade and widens through high school and college, where three times as many men as women earn computer science degrees (Tarlin, 1997). The impact of this on women's career opportunities can be significant. The National Science Foundation estimates that by the year 2020, one in every four new jobs will be technically oriented (Tarlin, 1997). Teachers need to be aware of the different tendencies between boys and girls in the way they perceive and use technology, and then structure learning opportunities that respond to these differences—while being careful to avoid stereotyping.

Research indicates that girls often receive less exposure to technology than boys (Tarlin, 1997; Miller et al., 1996; Neuman, 1991). In school, girls often lose control of the computer to more assertive boys, and they are often greatly outnumbered in computer science classes (Tarlin, 1997; Sutton, 1990). High school girls account for only 26 percent of all elective computer use and only 20 percent of all computer-based game-playing activities in school (President's Committee, 1997). At home, boys and girls use computers about the same amount of time, but they use them for different purposes. Girls are more likely to use a home computer for school work and word processing, while boys are nearly twice as likely to play noneducational computer-based games (President's Committee, 1997).

Computer games are viewed by some as partly responsible for creating a gender gap in computer use. In the middle grades, when adolescents are forming sexual identities, girls often lose interest in the computer because they begin to perceive it as male-oriented (Sanders & Stone, 1986; Tarlin, 1997; Rice, 1995; Miller et al., 1996; Zehr, 1998; Honey et al., 1991). Computer games are often young people's first experience with technology, and these are dominated by images of competition, sports, and violence (Tarlin, 1997). Also, 74 percent of the characters are male, and the female characters are usually "damsels in distress" (Tarlin, 1997).

Amanda is a student aide in the computer laboratory at Romig Middle School in Anchorage, and she shares this observation: "More guys are into video games because most of the games are male-oriented, shooting games and things like that. Most girls aren't really into that. Like, I recently returned a video game because it was just about this woman and she's, you know, big breasted, and she's supposed to be all beautiful. It's just not realistic."

There is further evidence that girls and boys perceive the computer differently. While girls generally see the computer as a machine that connects people, facilitating communication and collaboration, boys often see the computer as extensions of their power over the physical world (Honey et al., 1991; Tarlin, 1997; Miller et al., 1996). This has important implications for teaching. Teachers will want to employ strategies that invite all students to use technology in support of their creative and intellectual impulses.

"Subtlety just won't work," writes Jo Sanders, coauthor of *The Neuter Computer* (1986) and author of *Lifting the Barriers* (1994). "To encourage girls to use computers, you have to say GIRLS loud and clear ...." To counter gender bias in computer culture, teachers can create a welcoming environment by choosing girls as well as boys to serve as classroom technology assistants, states Sanders. They can ensure that learning resources include computer programs that appeal to girls. Girls often prefer creative, open-ended computer situations—nonlinear games and activities where there is more than one right answer, or more than one way to proceed (Tarlin, 1997).

When recruiting for student computer aides at Romig, technology coordinator

Strategies to engage girls

- At mathematics, science, or technology fairs, make sure at least 50 percent of the tour guides and demonstrators are girls
- When structuring a lesson involving data, include subjects that are likely to interest girls, for example, popular songs and women's sports
- Invite girls to be computer aides, saving or deleting files and logging computers off the network at the end of the day
- Present information on technology occupations and earnings, and invite female role models to speak to the class
- Have girls and boys create a display featuring women in mathematics, science, and technical careers, and exhibit it in a prominent place—these can be women from the community as well as famous individuals

—Jo Sanders (1994)
Lifting the Barriers

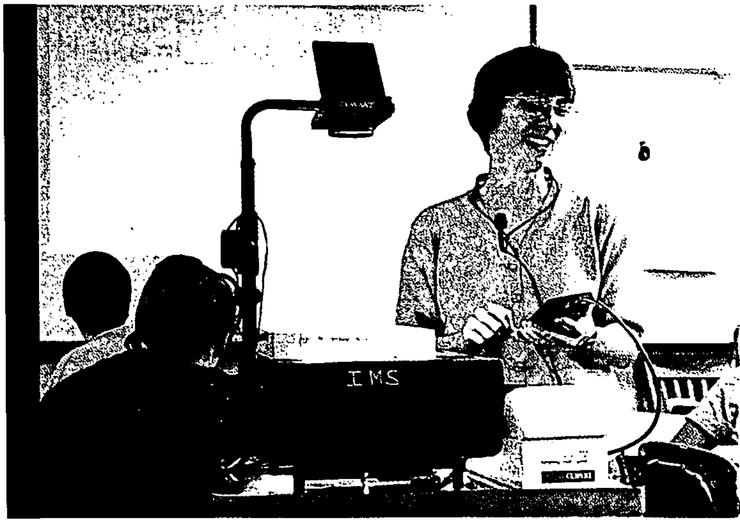
Graphing calculators: A window to understanding

"Are we supposed to be bonding with our calculators or something?" The joke earns Brian laughs from his classmates. But that's pretty much what Leslie Nielsen, a mathematics teacher at Issaquah Middle School in Issaquah, Washington, hopes will occur as her students use graphing calculators to explore the concept of a coordinate plane.

Some of Nielsen's seventh- and eighth-grade students are struggling to understand the concept of quadrants, *x* and *y* coordinates, and ordered pairs. Nielsen believes that they will develop a better understanding of these mathematical ideas with the aid of graphing calculators. With the calculator's large screen, a student can create a coordinate plane and then move the cursor around the quadrants of the graph, observing how the coordinates of the cursor change as the cursor moves.

Students can then plot and graph ordered pairs, and, using the "draw" command on the calculator, they can graph points, line segments, and circles. By changing the coordinates of a point, students can see the figure change as the coordinates are altered. The graphing calculator's screen allows students to see their data and graph simultaneously. This enables students to visualize integers, helping to reinforce their understanding of number relationships.

But first, Brian and his classmates need time to explore—or "bond" with—their calculators. Nielsen has augmented her classroom supply of calculators for the weeklong project by borrowing 20 TI-83s from Texas Instruments, as well as an overhead calculator. Thus, each student can work on his or her own calculator, while collaborating with other students and watching brief demonstrations by Nielsen on the overhead graphing calculator.



"We all have calculators now, cool!" says Brenda, poking at the blue and yellow buttons on her keypad as she explores the calculator's functions.

"Yeah, we got those really weird calculators," says, Andrew, obviously pleased to be investigating this new tool.

Before long, the students are ready for a guided exploration of a coordinate plane and the functions of the calculator. Nielsen hands out a set of activities that will guide students' exploration. Their first activity is to speculate about which areas of the graph are positive and which are negative. They verify their thinking with the graphing calculator, moving the cursor between quadrants and observing where the coordinates of the cursor are positive and where they are negative.

Nielsen reinforces this activity by asking students to turn to two graphs on their worksheets. Using colored pencils, students shade in red those quadrants in which the *x*-coordinate is negative, and shade in blue those quadrants in which the *x*-coordinate is positive. They then mark in black where the value of *x* is zero on the *x* axis. They repeat this procedure for the *y*-coordinate. The combination of visual and hands-on materials provides a powerful—and fun—reinforcement of these important concepts.

Students are now ready for the next step. Nielsen demonstrates on the overhead graphing calculator how to create a "friendly" window. This means that students will design a window that provides a good view of the graph and, for this particular lesson, displays coordinates rounded to the nearest tenth. As students enthusiastically begin creating their windows, Nielsen moves about the room, observing and guiding students as they create coordinate planes and draw points on their graphs.

Nielsen stands by as Janine uses the directional keys on her calculator to move the cursor around on the screen. For each key push, Janine moves the cursor one space, noticing that when she moves the cursor around the graph, the numerical coordinates change. Then, as she moves the cursor across the *x*

axis, and then across the *y* axis, the coordinates change sign from positive to negative.

Nielsen asks her, "What did you discover about the *x* axis?"

Janine studies the screen carefully, moving the cursor back and forth. Then, with a smile of triumph, she describes the value of the *y* coordinate: "That all of this side of the graph is positive, and all of this side is negative."

There are many such little victories today. As the students become more skillful in using the calculators, they create triangles, rectangles, and circles on their graphs, engaging in an exploration that will eventually lead to an understanding of slope and intercept. Students also learn how to create a friendly window on the graphing calculator, a window that will display only the pertinent information on a graph. In learning to create a friendly window, students are introduced to the important mathematical concepts of *domain* and *range*. Students learn that the set of values from the minimum to the maximum value of x is known as the domain of a function, and, similarly, the set of y values is the range. Students will revisit this vocabulary later when they will be graphing functions, says Nielsen.

"To view the graph of a function, the student must determine where on the coordinate plane to look. This is the process of choosing a good window on the calculator," she says. "The students need to ask themselves, 'Where is my playing field?' For example, if they want to see a parabola on their graph, they have to create a window that will display it."

The graphing calculator's display and computation capabilities enable these middle-grade students to make a meaningful transition from concrete to abstract thinking. At the end of the weeklong unit, Nielsen asks her students to write a letter to an imaginary classmate who has been absent. She asks them to describe what they have learned and what they think about using graphing calculators.

In her letter, Ashley writes, "I have enjoyed using the graphing calculators. It was a fun break from book work. I am happy that I know about the x and y coordinates, and where they are negative and positive, for (high school) next year. They were a little confusing at first, but when I got the hang of them, they were really fun."

Sean writes, "It was really boring at first because I didn't understand what we were doing, but in the end I understood, and it was really fun."

Megan agrees: "It was better using the calculators because we got to do hands-on stuff and visualize for ourselves, and I think it sticks in our heads more. It was fun. We should use them more often."

Naturally, Nielsen is pleased by these responses. Using the graphing calculator to introduce the concept of the coordinate plane proved to be an effective strategy.

"I could have launched right in there and simply lectured, 'Okay, here's a coordinate plane: over here's positive, over here's negative,'" says Nielsen. "But I don't think that would help students gain a very meaningful understanding. The graphing calculator gives students a way to explore these concepts for themselves, make conjectures, and verify their thinking."

The middle grades are a critical time in mathematics learning, says Nielsen, and the graphing calculator can help students to obtain a level of mastery that will enable them to achieve in mathematics throughout their school years.

"If we don't hook them on mathematics now, we'll lose them," Nielsen says. "If we don't turn them onto math now, and show them why it's important and even interesting, then the students who aren't 'getting it,' may *never* get it."

Darla Jones asks teachers: Who are your responsible kids?

"I don't care so much if they know everything about computers," says Jones. "I care more that they're responsible, and that they are able to teach other kids how to do something—the training on the computers can come later."

This strategy throws a wider net, she says, inviting girls as well as boys to apply for these high-status positions.

Students with special needs.

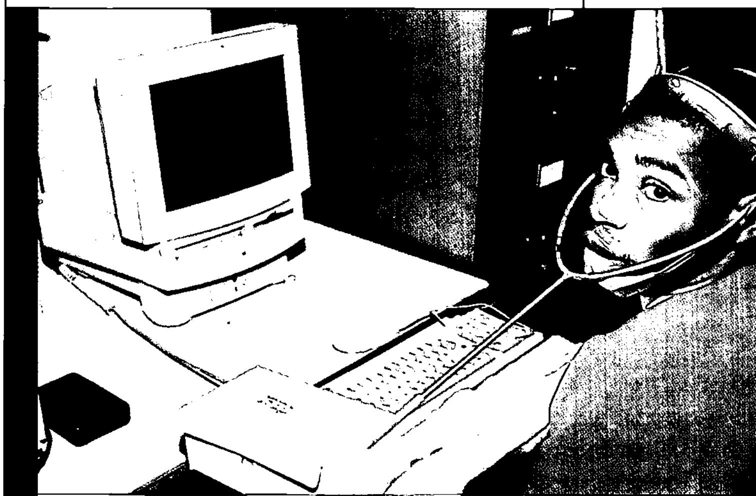
Computers and calculators have been particularly effective for students with special needs (Milone, 1996; Shumway, 1992). Noting that technology often empowers special-needs students to perform at higher levels, a report by the Panel on Educational Technology (President's Committee, 1997) urges that students with learning disabilities, behavioral disorders, emotional problems, or physical disabilities be afforded the maximum possible benefit of educational technology.

Educational technology can be fitted with adaptive devices that can give students with disabilities equitable access to these tools (Milone, 1996). With adaptive devices, technology can break down barriers faced by some students with disabilities, enabling them to benefit from that which technology offers all students: greater learning and classroom participation, and the development of valuable career skills (Milone, 1996).

The organizations below offer disability-related services and resources. These companies are listed, with contact information, in the "Resources and Bibliography" section at the back of this publication, either under "Organizations" or "Suppliers."

ABLEDATA—a national database of assistive technology information.

Apple Office of Special Education—Maintains an online and print database of assistive devices, software, networks, organizations, and publications concerning disabilities.



Equal Access to Software and Information—Conducts online and onsite workshops and projects in science, engineering, and mathematics, and provides information on how to design accessible Web pages.

IBM National Support Center for Persons with Disabilities—Offers assistive devices and software products that make the computer more accessible to those with vision, hearing, speech, mobility, and attention/memory disabilities.

The National Center to Improve Practice in Special Education Through Technology, Media, and Materials—Promotes the effective use of technology to enhance educational outcomes for students with sensory, cognitive, physical, and social/emotional disabilities, and maintains an online network for teachers, parents, researchers, and others.

Common instructional technology

Below are some of the technological tools that teachers commonly use in their teaching. There are other valuable tools, such as simulation software and scientific probes, but those listed below are often more readily available to teachers.

Standard calculators. NCTM standards indicate that middle-grade students should have ready access to calculators. With calculators, students can move beyond time-consuming computations and focus on problem solving and other important content. Studies indicate that students' attitudes and performances improve when they use calculators in their mathematics learning. Calculators can help middle-grade students overcome traditional barriers, such as weak computation skills and language barriers, freeing them to experience more complex mathematics learning (Branca et al., 1992).

"Reform measures consistently advocate an inquiry-oriented learning environment that promotes the development of students' mathematical power. The calculator can be used effectively in establishing such an environment if it is used as a tool for mathematics explorations and investigations." (Bitter & Hatfield, 1992).

Research indicates that calculators do not undermine students' knowledge of basic facts (Shumway, 1992; NCTM, 1989). As a matter of fact, calculators can be

used to teach, practice, and reinforce basic skills. For example, because calculators provide immediate feedback, students are less likely to write down wrong answers—an act that reinforces the error (Shumway, 1992).

Some teachers hesitate to allow their students to use calculators because some standardized tests prohibit or restrict the use of calculators. However, calculators should not interfere with assessment. While it might be inappropriate for students to use calculators during tests that target some computational skills, it can be valid for them to use calculators when the assessment goal is to isolate students' understanding of complex concepts and problem solving (Bitter & Hatfield, 1992). Allowing students to use calculators on tests that target higher-order concepts will help ensure that students are not being penalized for weak computational skills.

The NCTM standards suggest that teachers select calculators that have the following features: algebraic logic, including order of operations; computation in decimal and common fraction form;

constant function for addition, subtraction, multiplication, and division; and memory, percent, square root, exponent, reciprocal, and +/- keys.

When determining whether to allow students to use calculators, teachers will want to base their decision on their instructional goals. Below are five questions and examples posed by the writers of the article, "Middle Grades: Access to Rich Mathematics" (Branca et al., 1992), to guide teachers in their decisionmaking.

Does the calculator allow students to more fully understand the concepts being presented? For example, calculators can enable students to understand the nature of exponents without engaging in repetitive multiplications. Students who have not yet mastered the algorithm for long division using paper-and-pencil methods can use the calculator to perform division operations, freeing them to focus on those concepts of division that are required in problem solving.

Can the concept be taught with an inductive approach? Valuable learning can take place when a student discovers a mathematical concept by exploring with the help of a calculator. For example, students can approach the learning of rules for decimal operations like real mathematicians. Starting with a blank piece of paper, they can generate various decimal computation problems, use the calculator to get the answers, and compare notes with their classmates to find and justify patterns observed in the results. Similar explorations can even lead students to discover the algebraic order of operations rules.

Will the use of the calculator facilitate the study of real-life applications? Numbers in real life are often messy. They can be very large or very small. Calculators allow teachers to pull timely and relevant problems about the economy and populations from news sources. The numbers connected to scientific research, rates of inflation, odds of winning the lottery, or salaries of popular singers and actors provide data that are more likely to engage students than data unrelated to real life.

Will using the calculator allow assessment to be focused on relevant educational objectives? Teachers can use calculators in assessment activities to measure students' growth in conceptual understanding and problem solving. For example, if a teacher's goal in a unit is for students to develop skill in solving word problems involving percents, the use of calculators in assessment can reduce computational errors with decimal operations—a skill that is not the focus of the unit.

Graphing calculators. Graphs provide middle-school students with a visual bridge between concrete and abstract mathematical concepts. Students can look at the graph and see a concrete

image representing abstract numbers. Graphing calculators, such as those produced by Texas Instruments and Hewlett Packard, can create numerical, algebraic, and geometric representations for the same problem situation, enabling students to analyze problem situations using a variety of mathematical models (Demana & Waits, 1990).

Charles B. Vonder Embse (1992) writes about the use of the graphing calculator in his article, "Concept Development and Problem Solving Using Graphing Calculators in the Middle School." Unlike other calculators, the graphing calculator contains a screen large enough to simultaneously display a student's keying sequence and answers to multiple problems. This allows the student to make immediate comparisons between the results of each problem, reinforcing mathematical concepts and processes, says Vonder Embse.

Seeing multiple lines of results displayed together on the screen can also make errors more apparent when a particular result doesn't fit the pattern of the others. This creates a valuable opportunity for the student and teacher to analyze where the error was made. It can provide the teacher with insight into the student's thinking process and enable him to identify any misconceptions the student might have about the mathematics. Students can correct and change entries by using the calculator's editing keys (Vonder Embse, 1992).

The graphing calculator's ability to display multiple lines also assists students in exploring numerical patterns and processes. The larger screen allows students to solve problems by repeatedly entering a calculation in which the value of a variable is changed. Students can create a table of these calculations, and the screen will simultaneously display

the numerical entries, the operational symbols, and the computed results. Students can estimate what the results might be and check their estimate against the calculator's answer. Thus, students can see the relationship between the chosen values and the computed results (Vonder Embse, 1992).

"Guess-and-check is a generic problem-solving strategy that can be used in many situations, and given modern technology like the graphing calculator, this process is also very efficient," writes Vonder Embse. "Guess-and-check causes students to refer continually to the original problem situation and helps develop intuition about mathematical processes and number sense."

Middle-grade students often have difficulty understanding the concept of variables and how they allow the generalization of numerical processes, critical concepts in algebra and higher mathematics (Vonder Embse, 1992). With graphs, students can visualize numerical relationships, and see how these relationships change when the numbers change (Knapp & Glenn, 1996).

The replay function of the graphing calculator allows students to repeat the last command line that was calculated, edit the command, and recalculate the result. For instance, Vonder Embse suggests that students can use this function in a problem-solving situation involving exponential growth, such as calculating the price of something as it increases in relation to the annual rate of inflation. The replay function of the graphing calculator frees the student to focus on the significance of the changing values.

One eighth-grade teacher uses graphing calculators to engage her students in investigating the linear relationship of two sets of data. For example, using data collected by the *American Journal of Public Health* on cigarette smoking in 12 different countries, students use their calculators to explore whether there is a relationship between the number of cigarettes smoked each year by adults and the number of deaths due to coronary heart disease. (For another example, see "Graphing Calculators: A Window to Understanding" on page 20.)

Spreadsheet tools. Like graphs, spreadsheets present students with a visual representation of mathematical relationships. The spreadsheet format keeps data neat and organized, making it easier for students to see how the relationships change when the numbers are changed. For example, in a lesson on finances, students can see numerical relationships in the spreadsheet format, which will help them to understand percentages and how they work when calculating interest. Spreadsheets help students to learn about place value, decimals, making calculations, seeing relationships, understanding variables, and working with large numbers (Knapp & Glenn, 1996).

Sometimes a spreadsheet program, such as Microsoft Excel, Number Cruncher by Pierian Spring Software, or ClarisWorks Office, is more efficient than using a calculator. When teaching a course on the mathematics of apportionment in U.S. history, one teacher found that the calculator was not the best tool for analyzing data obtained from the U.S. Census Bureau.

"Even when done with a calculator, the investigations with this problem setting are often tedious, and the students quickly become bored with what [appear] to be mundane arithmetic calculations," states Robert Iovinelli in *The Mathematics Teacher* (Iovinelli, 1998).

When he allowed his students to create computer spreadsheets to do the calculations, their motivation greatly increased and the quality of work improved. In addition to allowing students to do projections, comparisons, and contrasts with data, computer spreadsheets enable students to save and reuse the data many times (Iovinelli, 1998).

How do you map an ocean floor? By ratio!

The mobile homes lining the circular drive through Forest Park Trailer Court are like some of the old birch trees shading the lane: craggy, listing on their foundations, but standing firm over the course of time. Established 50 years ago, this mobile home park in Anchorage was founded before Alaska was even proclaimed a state. Since then, people have continued to move into the area, no doubt for its loveliness, proximity to downtown, and hilltop views of Westchester Lagoon and Cook Inlet.

Today, the wooded neighborhood of Forest Park envelopes not only the tidy trailer court, but a mix of modest residences, "trophy" homes, and the odd mansion or two. Its residents reflect the rich diversity of West Anchorage.

While Forest Park has quietly diversified over the years, bringing together a community of people from a wide array of economic levels, the larger area of West Anchorage has undergone a more visible and less tranquil transformation. Streets have given way to boulevards lined with franchises and superstores. Apartment complexes often overshadow single-family residences. Trendy shops share clientele with a few famously seedy bars. And a newer element has added its influence to the area: youth gangs.

In this milieu lies Romig Middle School, on the edge of Forest Park. Like the community, the students at Romig are diverse in their ethnic and economic backgrounds. Forty-four percent of Romig's students are minority, largely Alaska Native, Native American, and Asian/Pacific Islander. While some students live in households with annual incomes of more than $65,000, one-quarter of Romig's students are from low-income families earning $22,000 and less. The student mobility rate is high at 50 percent, with many families moving repeatedly in search of affordable housing and employment.

To respond to the needs of its students, Romig employs a variety of programs and policies. Its bilingual education program serves about 100 students. It has Indian and migrant education programs. There are three full-time counselors. To discourage gang affiliations, the school enforces a dress code and trains teachers to recognize gang symbols. Recently, staff adopted a team-teaching model, matching groups of students with teams of teachers to create a supportive and effective learning environment.

One of Romig's most visible programs is in technology. To Principal Sophia Masewicz, an African-American educator who has been at Romig for seven years, technology is an important component of providing all students with an equitable and quality education. Students often gain self-esteem and valuable skills when they use technology in their learning, she says, which can be especially important for students from lower socioeconomic backgrounds.

"I see technology as a great vehicle for kids who haven't had the advantages that many students have had. It connects them with what they'll face in the real world, so that they're not displaced in society," she says.

While Romig's technology resources are significant by many schools' standards—two computer and multimedia laboratories and computers in many classrooms—most of the tools were obtained only a couple of years ago.

Therefore, many teachers are in the early stages of learning how to incorporate technology into their instructional practices.

The teachers on the Pioneer Peak Team, Rachel Nosek, Jon Lindsay, and Kathryn Reiman, are collaborating with technology coordinator Darla Jones to design a multidisciplinary project on oceanography for their seventh- and eighth-grade students. The unit focuses on the formation of volcanic ocean vents along the Juan de Fuca Ridge off the southeast coast of Alaska. Students research the Internet, CD-ROMs, and other library resources to learn about marine life, continental drift, and geologic forces. They use computer spreadsheets and word processing programs. They also produce two scale models, one depicting the Juan de Fuca Ridge and another illustrating an aspect of oceanography that interests them.

The project is ambitious, says mathematics teacher Rachel Nosek, but she believes the students will benefit from the challenge. Knowing that this is when some students drop out of school, Nosek is anxious that her students experience success in school and are academically prepared for the rigors of high school.

The students of the Pioneer Peak team, like many groups of students, are very diverse in their backgrounds and abilities. But they begin the project with shared curiosity and a desire to succeed. There is much for them to explore and learn. In Jon Lindsay's science class, students study bathymetric maps from the National Aeronautics and Space Administration Web site, Ocean Planet (http://seawifs.gsfc.nasa.gov/ocean_planet.html). Based on these maps, students construct a paper model of the Juan de Fuca Ridge. In Kathy Reiman's language arts class, students use book and Internet sources to research aspects of oceanography. Chantelle investigates the effects of the Exxon Valdez tanker oil spill on marine wildlife in Prince William Sound (http://www.oilspill.state.ak.us/). Michael researches the new Seward Marine Education Center (http://www.sfos.alaska.edu:8000/SMEC/), and Tiffany explores how the Aleutian Islands were formed.

In mathematics class, Nosek introduces students to the concept of ratio to prepare them for the task of converting the bathymetric map scale measurements to a model scale. Using Color Mixer, an interactive program in Odyssey of Discovery's mathematics software (Pierian Spring), students develop their understanding of ratios by manipulating the hues of a color wheel. Later, Nosek demonstrates how to convert metric scale measurements from the bathymetric map to an appropriate model scale. Students practice the conversions on paper before creating computer spreadsheets in ClarisWorks. The spreadsheet program will do the many iterative calculations in a matter of seconds, enabling students to avoid the time-consuming task of doing them all by pencil and paper. With these calculations in hand, students construct their paper models of the Juan de Fuca Ridge.

Lastly, students create a second model. Melissa builds a miniature town that has been razed by a hurricane. Jasmine depicts an El Niño weather pattern. And Walter carves a soap stone whale. During an in-class science fair, students portray the scaling ratio beside their models, providing viewers with a key to understanding how large the actual figures would be.

The multidisciplinary nature of this project incorporates many of the recommendations made by NCTM for the middle grades: applying the concept of ratio in a real-world task; solving problems in other disciplines, such as science and art; and using a variety of computing methods, including mental arithmetic, paper-and-pencil calculations, and technology.

Nosek believes that extended projects incorporating technology are especially effective in preparing her students for high school and beyond.

"It's important that they learn now how to use technology to enable themselves to do more work, to do efficient work, and to do applicable work," she says. "When they start high school, if they already have the ability to create and use a spreadsheet, for example, they're going to be one up on many other kids."

At Romig Middle School, Tricia and her classmates are engaged in a multidisciplinary project on oceanography involving science, mathematics, and language arts. Students are building three-dimensional models of the Juan de Fuca Ridge, a series of volcanic ocean vents in the Pacific Ocean. To accomplish this, they must convert the numerous scale measurements depicted on a bathymetric map (a map that represents the topography of the ocean floor by measuring from sea level down to the sea floor) to a different scale that is appropriate for their models. The students soon realize that it would be more efficient to program a computer spreadsheet to do the calculations.

"We have about 30 or 40 conversions to do, and if you don't have a spreadsheet, you're going to have to do it all by hand," says Tricia. "So, with a spreadsheet, it doesn't take as much time, and it lets us get to the other stuff that we're doing, like building our models."

John Lorenz teaches seventh-grade mathematics at Hellgate Middle School in Missoula, Montana. He and his students use Microsoft Excel spreadsheet and graphing applications for many aspects of mathematics. Using spreadsheets enables Lorenz's students to explore patterns and make connections within mathematics as well as between mathematics and other disciplines, he says. Many of his students develop a better understanding of algebraic symbolism and manipulation by working with spreadsheets. Spreadsheets also make real data available for students to explore various graphing formats, he says, such as bar, pie, and line graphs, and box-and-whisker plots.

"They learn how to use their graphical representations to paint a picture that best represents their data," Lorenz explains. "Many students customize their graphs, making them three dimensional, changing backgrounds, fonts, and often copying graphics from the Internet."

In a unit on aviation and basic navigation skills, Lorenz's students use spreadsheets to help them to review and expand their understanding of many basic computational skills, such as working with whole numbers, decimals, fractions, and percents. Students also develop number and operation sense. Sometimes, they create algorithms to make their spreadsheets function more efficiently.

"The use of the spreadsheet allows students to explore, analyze, and make predictions based on statistical concepts," says Lorenz. "Precious time can be better spent collecting and organizing data; constructing, reading, and interpreting tables; and designing charts and graphs, instead of wasting time on tedious pencil-and-paper calculations."

(For more examples of using spreadsheets, see "Getting Started" on page 6.)

Geometric construction tools. The NCTM standards state that the mathematics curriculum for the middle grades should take students beyond simply memorizing relationships, definitions, and methods of measurement and construction. Using computer software whenever appropriate, students should be involved in active and indepth explorations and analyses of geometric shapes and concepts (NCTM, 1989).

Geometric construction software can enable middle-grade students to investigate concepts that were once thought to be unattainable for students of this age group. Students can explore transformations of geometric figures, represent and solve problems by using geometric models, and make connections to algebra and other areas of mathematics. Geometric construction software allows teachers to create an environment in which students can more deeply investigate and use geometric concepts and relationships, rather than merely memorizing definitions and formulas (Manouchehri et al., 1998).

Students can construct geometric figures with Euclidean construction methods or transformational-geometry techniques (Manouchehri et al., 1998). They can also construct two- and three-dimensional shapes on a screen and then flip, turn, or slide them to view them from a new perspective:

"Explorations of flips, slides, turns, stretchers, and shrinkers will illuminate the concepts of congruence and similarity. Observing and learning to represent two- and three-dimensional figures in various positions by drawing and construction also helps students develop spatial sense" (NCTM, 1989).

Geometric construction software creates interactive environments in which students can develop spatial sense by visualizing and representing geometric figures dynamically. Students can explore transformations of geometric figures, and they can problem solve using geometric models (Manouchehri, Enderson & Pugnucco, 1998; NCTM, 1989). The Pythagorean theorem is one of the most important properties in geometry to be introduced in the middle grades (NCTM, 1989). Students can discover this theorem by exploring and manipulating right angles on the computer.

There are several brands of geometric construction software packages, including Geometer's Sketchpad (Key Curriculum Press), Cabri Geometry II (Texas Instruments), and Geometric superSupposer (Sunburst Communications). Geometric construction software can facilitate students' development from concrete to abstract thinking, foster a "conjecturing spirit," and improve students' mathematical thinking (Manouchehri et al., 1998).

Multimedia tools. Multimedia technology facilitates learning that involves both verbal and visual information (Moore et al., 1994). By providing concrete elements such as text, graphics, sound, and animation, multimedia engage learners' multiple senses. Thus, the information is more likely to be stored in long-term memory (Moore et al., 1994).

With multimedia, students can be more self-directed in their inquiries, which allows them to pursue their curiosity and to think more deeply. Students who have difficulty expressing themselves verbally or in writing are often able to successfully communicate their ideas and demonstrate their knowledge by creating multimedia presentations.

"With HyperStudio, you can make your own little computer game that shows what you're reporting about," says one eighth-grade girl. "It's more colorful and fun than just writing about it. It makes learning a lot more fun."

Multimedia computer programs combine text, video, sound, graphics, still photography, and hypermedia. These elements, brought together in one powerful and easy-to-navigate environment, provide learners with multiple learning cues. Anecdotal evidence of the efficacy of multimedia on learning is growing, especially indications that it enhances higher-order thinking and problem solving, skills that are not easily measured by traditional testing (Ward, 1994; Moore et al., 1994).

Multimedia can help students to make direct connections between symbols and the real world by enabling them to transform one symbol system into another, such as changing text into voice or numbers into graphs (Moore et al., 1994). With multimedia tools, such as HyperStudio (Roger Wagner Publishing, Inc.) or Kid Pix Studio (Broderbund Software, Inc.), students' power to represent multiple symbols is greatly increased. These multiple symbols help students to develop pattern-recognition skills and to explore concepts from a variety of perspectives (Moore et al., 1994). Additionally, in a multimedia environment a student will engage in a high level of interactivity—an essential element of effective teaching and learning.

Internet tools. From the Internet, teachers and students can access a wealth of archived and real-time information. There are online libraries, museums, and encyclopedias; there are government and other official reports; and there are real-time scientific data pertaining to global weather, earthquakes, astronomy, and ocean temperatures (Steineger, 1998). Students often are very eager to explore these rich online resources.

"It allows you to get a lot more information, and it makes it more fun than just book learning. When you are just looking in books, it sort of bores you," explains a student at Romig. "When you have the computer in front of you, you're able to control what you want to look at. It gives you a greater feeling of accomplishment when you find what you're looking for on the Internet."

Internet browsers, such as Microsoft Internet Explorer, Netscape Navigator, and Mosaic, are applications that interpret hypertext markup language (HTML) and present the Web page to the viewer. A teacher will likely use one of these browsers to "surf" the World Wide Web. To help students focus their Internet explorations, a teacher will want to structure the activity carefully, sometimes bookmarking useful Web sites in advance and teaching students navigation strategies.

There are two basic ways of conducting online searches: with Internet directories and search engines. Directories, such as Yahoo! (http://www.yahoo.com), organize information into browsable categories, such as "education," "reference," and "science." Search engines, such as Alta Vista (http://www.altavista.com), scan databases containing some 140 million Web pages by keywords and then display the search results in an annotated list (Derby, 1997).

These Internet tools can also help teachers find online educational games, instructional resources, and curricula. For a listing of online teaching resources in mathematics and science, see "Electronic Resources" on page 48. For tips on conducting effective Internet searches, see *Internet Basics*, available online (http://www.netc.org/basics/).

Through electronic mail on the Internet or a local area network, teachers can communicate with colleagues, expert sources, parents, and even their own students. It can help overcome the isolation felt by teachers who have scarce time for collegiality and professional development. Teachers can also structure situations in which students use e-mail to collaborate on a project with students from a distant school, or develop their writing skills by exchanging correspondence with "key-pals" (Leu & Leu, 1997). Students can confer with mentors and query experts by e-mail.

Finally, teachers and students can create classroom Web pages on the Internet. The Web pages can contain students' descriptions of classroom activities and projects, copies of student work, and links to other useful Web sites. Students are usually proud to have their work published on the classroom Web page (see the section, "Other Important Considerations" on page 40 for information about obtaining permission to publish student work).

Parents who have access to the Internet can see some of the work taking place in their child's classroom (Leu & Leu, 1997). A classroom Web page is also a convenient location to place links to online resources that are relevant to a particular assignment. Teachers and students can place these and other links on their Web pages with proper copyright permissions. Then the information will be accessible to other Internet users, including students, parents, and other educators.

Web pages are usually created in hypertext markup language (HTML). Teachers and students can learn this programming language, or the teacher can obtain an HTML editor, software that will convert what has been typed with a word processor into the programming language (Leu & Leu, 1997). Graphics and photographs can also be placed on the Web pages. (For another example of an Internet-based activity, see "Getting Started" on page 6.)

Portable computers and "smart" keyboards. Portable computers and "smart" keyboards enable teachers to maximize computer resources in the classroom. Portable computers, such as the Apple eMate and AlphaSmart Pro, are laptop-sized computers that often come with word processing, drawing, spreadsheet, and graphing capabilities. (Note: Apple Computers, Inc. announced in early 1998 that it will no longer manufacture the Apple eMate 300, though it will continue to develop "mobile computing" with Mac OS-based products.) Students enter data into the portable computers by keyboarding or touching a stylus to the screen. Students can create preliminary work on the portable computer, then download files to a desktop computer for polishing and printing.

These portable computers are rugged and run on batteries. Students can carry them into a variety of learning environments, enabling them to have immediate access to computer technology whether they are working in the library, in a laboratory, outdoors, or at home. When situations require that individual students, or small groups of students, work on a computer in the classroom, but there aren't enough desktop computers to go around, these portable computers can be an effective substitute.

Succeeding with minimal resources

Students need frequent access to technology to benefit fully from technology's power to enhance higher-order learning (Knapp & Glenn, 1996; Sandholtz et al., 1997). Greater access and learning is usually achieved by placing available technology in the classroom, rather than locating it in a separate computer laboratory (Milone, 1996; Valdez & McNabb, 1997; Sandholtz et al., 1997). However, a teacher's classroom does not need to be technology rich. The key is to integrate available technology into the curriculum effectively. In fact, writes Michael Milone (1996) in his book, *Beyond Bells and Whistles: How to Use Technology to Improve Student Learning,* "even minimal applications of technology that support the curriculum are more effective than large-scale systems that function in isolation."

Computers in the classroom. While it is best to have at least one computer for every four to eight students (Valdez & McNabb, 1997; Means & Olson, 1997), access to fewer computers doesn't

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The teacher who has only one classroom computer and access to an overhead projection system, for example, can use the computer as an "electronic chalkboard" that the entire class can view at the same time (Knapp & Glenn, 1996). This arrangement can be effective for whole-class demonstrations and discussions. In this way, a single classroom computer can make those times when lecture and demonstrations are appropriate a more interactive and visual learning experience (Demana & Waits, 1990).

Another way to maximize the lone computer is to connect additional monitors to it. This allows students to group around available monitors while a student or the teacher operates the computer (Knapp & Glenn, 1996). Both of these arrangements allow the teacher or a student to demonstrate how to use software, the Internet, and other applications available on the computer.

"Meaningful technology-supported, project-based instruction requires a high level of access to the sorts of technology tools that researchers and other professionals use on a daily basis ...."

— Henry J. Becker (1994)
Analysis and Trends of School Use of New Information Technologies

Later, when students have practiced using the applications and are reasonably proficient, teachers can invite them to use the computer as a classroom resource for their projects and activities. This could include using a database to obtain information about global warming or world populations, designing a handout or publication, or performing small-group investigations (Knapp & Glenn, 1996).

The lone computer can also significantly increase classroom resources. The Internet, CD-ROM, and videodisc resources give students access to worldwide information sources such as encyclopedias and dictionaries, weather and astronomy data, government and research institute studies and databases, atlases and almanacs, museums and libraries.

Teachers will want to avoid granting students permission to use the computer as a reward for good work or behavior. Rather, teachers should reinforce the notion that the computer is a powerful learning tool by integrating it into the core curriculum and making it equally available to all students (Milone, 1996).

Computers on mobile carts. A teacher whose school has limited technology resources can suggest ways that the school can make the most effective use of these available resources. For example, computers and printers, monitors and video cassette recorders, and digital and video cameras, can be arranged as a unit on mobile carts (Milone, 1996; Sandholtz et al., 1997). These carts can be moved from classroom to classroom as needed.

For the teacher who is attempting to integrate technology into the regular curriculum, this arrangement is sometimes more effective than one which places all of the school's available resources into a computer laboratory (Sandholtz et al., 1997). While a computer laboratory can be effective for some purposes, and many schools choose this option, it does separate these powerful teaching and learning tools from the classroom where most of the learning takes place. With the resources on mobile carts, teachers will still need to share the technology and adhere to a schedule, but they can bring these resources into the classroom

where students can use them during regular classroom activities.

When the Milton-Freewater School District received a technology grant from the state of Oregon, the district chose to place five mobile multimedia carts in each school rather than create computer laboratories.

Marilyn McBride, principal of Ferndale Elementary and chair of the district's technology planning committee, explains their rationale succinctly: "We don't walk down the hall and say, 'Here's our pencil room. Now, for 40 minutes we're going to work with pencils.'" Students need ready access to the technology, she says, and the most effective way to achieve that is to place it directly in the classroom.

Another way a school can get available technology into the classroom is to obtain a set of 25-30 portable computers. These are lap-size computers that contain word processing and sometimes spreadsheet, drawing, and other applications (Milone, 1996). Teachers can reserve a set of portable computers for classroom projects or field trips, enabling every student to work at a computer. After composing text and creating tables and graphs on the portable computer, students can download their work into personal files maintained on the desktop computer in the classroom. In this way, portable computers can extend the power of the single classroom computer. (See the section, "Common Instructional Technology" on page 24 for more information about portable computers.)

Computers in laboratories. Those who advocate placing computer resources in laboratories point to some advantages (Means & Olson, 1997). For a school that is just beginning to acquire technology, locating the resources in a laboratory that is overseen by a technology coordinator become "instant experts." The technology coordinator can design technology-based activities and maintain the computer laboratory while teachers are developing computer skills and learning how to integrate technology into their curriculum. Also, teachers can consult the technology coordinator and collaborate on designing projects that are directly linked to the teachers' classroom curriculum (Means & Olson, 1997).

Romig Middle School in Anchorage places most of its resources in two computer laboratories. One contains older equipment and is used strictly for computer skill-building, such as keyboarding and programming. The other is a multimedia laboratory with newer equipment and software. The multimedia laboratory is reserved for classroom work on core curriculum.

"Our goal is ultimately to have computers in the laboratories and at least five in each classroom," says Darla Jones. "But it depends in part on where your staff is in readiness. There were no computers in this building seven years ago. Now that we have them, teachers have gotten very interested in using computers, but they're still learning how to incorporate them into their teaching. It's a difficult thing to do with a class of 30 students, even if you really know what you're doing. Reserving the computer laboratory for classroom work is one way to integrate technology directly into the curriculum."

Research indicates that this arrangement can be effective (Means & Olson, 1997). Teachers can maximize their students' access to the computer laboratory by allowing students to leave the classroom to go to the lab whenever appropriate. Also, schools can arrange to keep the laboratory open during lunch, and before and after school (Means & Olson, 1997).

Changing classroom roles

Students often respond to the interactive nature of technology by spontaneously helping each other on the computer or calculator, for example, and sharing ideas and their accomplishments with their peers. This often prompts teachers to structure cooperative learning projects more frequently (Means & Olson, 1997; Valdez & McNabb, 1997). In this cooperative environment, teachers and students adopt roles that are different from those in traditional classrooms. When a teacher integrates technology into her curriculum in ways that are congruent with standards-based teaching, students will often become more self-directed (Sandholtz & Ringstaff, 1996). Students will make decisions about generating, obtaining, and manipulating

information. Frequently, they will define some of their own learning goals.

The teacher in this scenario supports students' work by setting project goals, providing guidelines, and suggesting resources (Means & Olson, 1997). She interacts with small groups of students, or individuals, making suggestions and guiding students in problem solving. Also, she frequently learns technology skills alongside—even from—her students. She is no longer sole dispenser of knowledge, but a leading team player.

"For some teachers this changed relationship is uncomfortable," write Knapp and Glenn (1996). "If a teacher sees his role as an information provider, emerging technologies and restructured classrooms will alter that role."

New role for teachers. The teacher is the essential component in a successful classroom, with or without technology. Nevertheless, when teaching with technology, teachers often find that their instruction is most effective when they share responsibility for learning with their students (Mandinach & Cline, 1994). As students share in the decisionmaking, teachers may not be able to anticipate or immediately answer all of the questions and responses that students might have concerning the curriculum or the technology being used (Mandinach & Cline, 1994). This can challenge teachers' content knowledge, their expertise with technology, and their willingness to be perceived by their students as a learner as well as a teacher.

"Taking risks and trying something new, when you don't know the outcome, is real important for students to observe," says physics teacher and technology writer Louis Nadelson. "It's important for them to realize that the world isn't a solved place where the answers are all 'in the back of the book.'"

Problem solving occupies a fair amount of a teacher's time when teaching with technology (Heid et al., 1990). Even with the help of technology coordinators or other technical support people, teachers often function as technical assistants, training students to use the hardware and software and troubleshooting when the technology doesn't perform as expected (Heid, Sheets, & Matras., 1990). Not only do teachers troubleshoot technical snafus, they often act as consultant and collaborator in students' conjecturing, working with the students to determine the validity of their hypotheses (Heid et al., 1990). When a teacher solves problems alongside his students, he is modeling persistence—an important life skill.

"As adults, it's good for us to occasionally experience the learning curve that kids are in all of the time," says Judith Chesnut, principal at Freewater School in Milton-Freewater, Oregon. "Patience and persistence: These are characteristics we want our kids to adopt, yet, as adults, we sometimes struggle with them."

Teachers report that instructional technology often changes their teaching practices in the following ways (U.S. Congress, 1997; Knapp & Glenn, 1996; Mandinach & Cline, 1994; Sandholtz & Ringstaff, 1996):

☐ They have higher expectations of their students, and technology enables them to present more complex tasks and material.

☐ They become more student-centered in their teaching. They use technology to facilitate more small-group and independent student work, and they believe that they are meeting students' diverse learning needs more effectively.

☐ Technology creates a safe context for them to become learners again. They also report feeling more professional and willing to experiment and see problems from multiple perspectives.

"Learning and teaching are going to be more deeply affected by the new availability of information [technology] than any other area of human life."

—American Association for the Advancement of Science (1997) *Blueprints for Reform*

New role for students. The student's role in a technology-integrated learning environment is also very different from the traditional classroom. The interactive nature of technology requires students to take more responsibility for their learning (Heid et al., 1990). Because it gives rise to cooperative learning situations, technology requires students to develop personal skills in collaboration and leadership. As they are involved in more open-ended investigations, students must learn to communicate their ideas and questions effectively (Heid et al., 1990).

Students must also learn how to be technical assistants, receiving and conveying technical knowledge with their peers and, sometimes, their teacher. Finally, in a technology-integrated environment, students will need to develop personal traits such as persistence and curiosity, patience and tact.

Other important considerations

A number of important issues are raised when one uses information technology, especially those technologies involving networks and multimedia. Teachers will want to discuss with their students the potential hazards of the Internet and establish classroom policies for using the Internet and electronic mail safely. Teachers will also want to be informed about district and school policies concerning publishing student work and photographs, as well as copyright practices. Teachers must inform themselves about current copyright law as it pertains to education and establish classroom guidelines for the lawful use of material created by others. Below are some suggestions for addressing these issues. Teachers can see examples of policies and guidelines by visiting the Web pages of some Northwest school districts listed at the end of this section.

Internet safety. While the Internet offers rich and seemingly endless resources that are especially useful to students and teachers, users should be alert to its possible dangers. Teachers can help students to be "street smart" as they navigate this largely unregulated environment that, like much of life, presents some risks.

"The Internet ... is not governed by any entity. This leaves no limits or checks on the kind of information that is maintained by and accessible to Internet users," states the author of *Child Safety on the Information Highway* (Magid, 1996), a brochure published by the National Center for Missing and Exploited Children.

Preteens and teenagers are particularly at risk because they use the computer without supervision more frequently than younger children (Magid, 1996). They might encounter sexual, violent, or other inappropriate material. By electronic mail, a child might divulge personal information to an unscrupulous person who may try to arrange a meeting with the child. Or a child might receive harassing, demeaning, or belligerent messages (Magid, 1996).

To minimize these risks, teachers will want to talk to students about Internet safety and proper use. Instruct students to click the "stop" function and alert the teacher as soon as they realize that they might be entering an inappropriate Web site. To discourage students from purposefully seeking inappropriate material on the Internet, one teacher tells her students that the computer keeps track of all of the Web sites they visit, and that she can check these records when necessary. (Most Web browsers, such as Microsoft Internet Explorer and Netscape Navigator, keep a record of Web sites visited in cache or history files.)

Also, instruct students to alert the teacher immediately if they receive a threatening or inappropriate message by electronic mail. Advise students not to divulge personal information, such as their home address, telephone number, and full name, to strangers over the Internet. Point out that, because they cannot see or hear the person they are communicating with over the Internet, the other person can misrepresent who they really are.

There are several resources available to help teachers develop safety guidelines for Internet use. The Educational Research Service has published *The Internet Roadmap for Educators* that includes safety guidelines as well as other information about using the Internet in the classroom. Copies can be purchased from the ERS, 2000 Clarendon Boulevard, Arlington, VA 22201. For information, call (703) 243-2100, Fax (703) 243-3922, or send e-mail to ers@ers.org

The guidelines published by the National Center for Missing and Exploited Children, *Child Safety on the Information Highway* (Magid, 1996), is directed to parents, but is also pertinent to teachers. Because students often do school work on home computers, teachers may want to make parents aware that these guidelines are available online at the center's Web site under "Publications" in the "Education and Resources" section (http://www.ncmec.org/). A free paper copy of the brochure can be obtained from the center by calling (800) 843-5678.

Also, the U.S. Department of Education publishes *Parents Guide to the Internet*, which is available either online (http://www.ed.gov/pubs/parents/internet/) or by calling (800) USA-LEARN.

Parent and student permissions. Most schools and school districts have policies about obtaining written permission from parents and students before publishing student work and photographs on the Internet and elsewhere. Teachers will want to obtain signed release forms from students and parents before uploading students' work onto an Internet server (Bruwelheide, 1995). This is also true for uploading photographs of students engaged in classroom activities. Some schools and districts in the Northwest have well-developed policies on parent and student permissions, Internet use, and copyright.

Copyright issues. At present, rapid advancements in information technology outpace some aspects of copyright law. Though lawmakers, educators, and others are working to clarify how the 1976 Copyright Act applies in today's world of information technology, it remains a complex issue (Ward, 1994; Bender, 1994; Bushweller, 1994; Bruwelheide, 1995). For educators who use the Internet and multimedia technology in their teaching, it can be difficult to determine what is lawful use of music, sounds, textual, and visual material. Nevertheless, teachers must be informed about current copyright law and practices. They must take responsibility for making lawful use of others' creations and guide students to do the same.

Janis H. Bruwelheide, a professor in the Education Department at Montana State University in Bozeman, is the author of *The Copyright Primer for Librarians and Educators*, second edition (1995). She provides a review of current copyright law, including a discussion of "fair use" privileges that permit some uses of copyrighted material for educational purposes. In addition to discussing photocopying, off-air taping, and the use of videotapes in educational settings, she includes sections on how copyright law pertains to multimedia, the Internet, databases, and other digital environments, and offers guidelines for developing multimedia work. In addition to Bruewelheide's book, there are several sources for information about copyright and "fair use" guidelines listed in the "Resources and Bibliography" section of this publication.

Examples of policies and guidelines. For examples of district and school policies and guidelines concerning Internet use and copyright, visit the following Web sites:

- Bellingham Public Schools, Washington (http://www.bham.wednet.edu/policies.htm).

- Eugene School District, Oregon (http://www.4j.lane.edu/4jnet/).

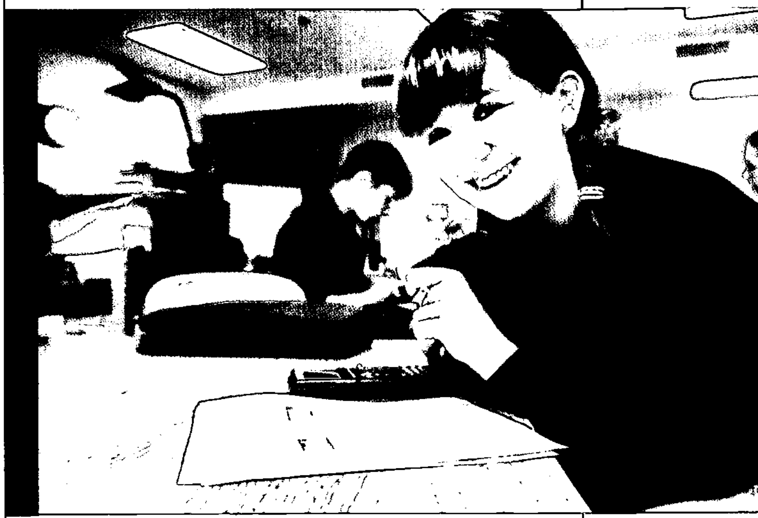
- Fairbanks North Slope Borough School District, Alaska (http://www.northstar.k12.ak.us/web/standards/standards.html#content).

☐ Kenai Peninsula Borough School District, Alaska (http://www.kpbsd.k12.ak.us/tech/permpub/permission.html).

☐ Multnomah Educational Service District Web site provides a link to From Now On, a Web site by Jamie McKenzie in Bellingham, Washington that contains information regarding copyright and Internet use policies (http://www.fromnowon.org/). The Multnomah Educational Service District Web page (http://www.mesd.k12.or.us) also has helpful information and links. From the ESD's home page, select "Index," then "General Information," and "Internet Training and Resources" to find links to sites offering information on integrating technology into instruction and to the online magazine for teachers, *Classroom Connect*.

Conclusion

Information technology is becoming an essential element of modern life: in the classroom, workplace, and at home. To ensure that all students have access to the benefits that technology can provide, many teachers are integrat-



ing technology into their teaching. This can be a challenging undertaking. It takes time and perseverance to master new technologies and to adapt one's teaching strategies. Nevertheless, technology's power to enhance student learning, and to prepare young people to participate fully in an information-laden society, has convinced many teachers to accept the challenge. The following pages provide a list of resources that teachers may find helpful as they strive to integrate technology into their teaching.

Resources & Bibliography

The Web site addresses (URLs) listed in the "Resources and Bibliography" sections were current at the time of printing, but may be subject to change. Normally, old Web site addresses will provide a link to the new site, but if one is not available, we apologize for any inconvenience.

Resources for further reading

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Electronic resources

The Ada Project: Tapping Internet Resources for Women in Computer Science
http://www.cs.yale.edu/HTML/YALE/CS/HyPlans/tap/tap.html

This site includes links to many online resources for women in computing.

Adventures of Jasper Woodbury
http://peabody.vanderbilt.edu/projects/funded/jasper/Jasperhome.html

This is a videodisc series developed at Vanderbilt University's Learning Technology Center that engages students in complex mathematical problem solving.

Center for Children and Technology
Education Development Center, Inc.
http://www.edc.org/CCT/

The center collaborates with other educational institutions in creating and researching new ways to foster learning and improve teaching through the development and thoughtful implementation of new educational technologies. The site includes descriptions of the center's research projects and its newsletter, *CCT Notes.*

The Dr. Data Quiz
http://www.un.org/Pubs/CyberSchoolBus/special/drdata/index.html

This site, maintained by the United Nations CyberSchoolBus, aims to bridge the social and statistical world by presenting students quizzes involving data on a particular topic, such as rain forests, refugees, and telecommunications. After registering to participate via e-mail or the Internet, students search for answers to the statistical problems, developing their own perspective on the issues as they construct their answers.

ED's Oasis
http://www.edsoasis.org/

This site offers curriculum resources for networked educators, providing links to interactive student Web sites, such as "Sky Math" and "Plane Math" for middle-grade students, and offering examples of effective classroom Internet use.

The Franklin Institute Science Museum's Mathematics Hotlist
http://sln.fi.edu/tfi/hotlists/math.html

The Web site of this Philadelphia, Pennsylvania museum provides a rich list of online mathematics games, biographies of women in mathematics and computer science, lesson plans, and other resources.

From Now On
http://www.fromnowon.org/techtopten.html

This educational technology journal provides a top-ten list of Web sites for educational technology emphasizing the use of new technologies as tools to support problem solving and decisionmaking.

Galaxy Mathematics List
http://galaxy.einet.net/galaxy/Science/Mathematics.html

The Galaxy Web site provides links to resources in algebra, applied math, calculus, geometry, number theory, statistics, topology, and vector analysis, and more.

GirlTECH
http://www.crpc.rice.edu/CRPC/Women/GirlTECH/GirlTECH95.html

This online program is a four-week teacher training series in developing and presenting materials related to gender equity and computer technology.

The Global Lab Curriculum
http://globallab.terc.edu/about/brochure.html

This is a program of TERC (Technical Educational Research Center) that engages students in inquiry-based, telecollaborative science involving real-world investigations in biology, chemistry, and physics. It aims to develop students' skills in telecommunication, multimedia, and information literacy.

Global SchoolNet Foundation
http://www.gsn.org

This site includes "K12 Opportunities," a Web page offering classroom projects that are technology based. It also includes the listserv "HILITES" which provides a discussion forum for teachers on such topics as integrating technology into the classroom. GSN also publishes articles about educational technology and provides links to other very useful online mathematics activities, a mathematics dictionary, information on women in mathematics, and more.

International Society for Technology in Education
http://www.iste.org/

This teacher organization is based in Eugene, Oregon, and aims to help K-12 classroom teachers and administrators share effective methods for enhancing student learning through the use of new classroom technologies. This site provides links to other online teacher resources and projects. ISTE publishes *Learning and Leading with Technology*, a journal on curriculum development and practical ideas for using technology in the classroom.

Internet Island
http://www.miamisci.org/ii/default.html

This Web site is maintained by the Miami Museum of Science and provides online help in using Netscape and integrating the World Wide Web into the classroom.

Just in Time Training: Technology Integration
http://www.open.k12.or.us/jitt/

This site is sponsored by the Eugene Public School District 4J through a grant from the Oregon Department of Education. The project provides teachers and schools with resources for teaching and learning about the World Wide Web and strategies for integrating technology into classroom instruction.

Kathy Schrock's Guide for Educators
http://www.capecod.net/schrockguide/

This site provides a classified list of sites on the Internet for enhancing curriculum and teacher professional growth. Links to mathematics education Web sites include curriculum, projects, interactive student sites for skill building and problem solving, mathematics reference material, and other useful resources.

The Learning Space
http://www.learningspace.org/

This is an online learning community that works to improve education in Washington state. The project trains teachers and administrators in the usage of telecommunication technologies and provides educators with a telecommunications infrastructure, facilitating collaboration and communication for the support of instruction and the increase of student achievement.

Life by the Numbers
http://www.mathlife.wqed.org/standard/index.html

This Web site is based on a 1998 documentary series by the Public Broadcasting Service. The series, which is available for purchase on videotapes, explores the role mathematics plays in work, education, high technology, and other areas of modern life. For a nominal charge, teachers can purchase a two-hour videotape providing highlights of the series and obtain a free teaching guide from Texas Instruments by calling toll-free (800) 842-2737 or going to their Web site (http://www.ti.com/calc/docs/ml-video.htm).

The Math Forum Teacher's Place
http://forum.swarthmore.edu/teachers/

This Web site provides resources for teaching mathematics at all levels, including links to curriculum, student-centered interactive activities, and teacher discussion groups.

MathLine
http://www.pbs.org/learn/mathline/

This is an online professional development program of the Public Broadcasting Service. The year long program is Internet and video based and offers teachers resources and training in standards-based instructional techniques, and opportunities to interact and collaborate with other teachers via telecommunications.

MathMagic
http://forum.swarthmore.edu/mathmagic

This is a K-12 telecommunications project that motivates students to use computer technology while gaining problem-solving strategies and communication skills. Challenges are posted in each of four categories (K-3, 4-6, 7-9, and 10-12). Registered teams pair up to engage in a problem-solving dialogue.

One Sky, Many Voices
http://onesky.engin.umich.edu/

This site has inquiry-based science program that utilizes current technologies such as CD-ROMs and the World Wide Web for the interactive study of current science. Students, teachers, parents, and scientists can participate from classrooms, homes, after-school programs, or other educational settings.

Oregon Public Education Network (OPEN)
http://www.open.k12.or.us/

In partnership with the Oregon Association of Education Service Districts, the OPEN Clearinghouse provides online information and statewide instructional support to Oregon educators on Oregon education reform, technology integration, and links to educational resources. OPEN strives to minimize the difficulties that teachers face when using the Internet and World Wide Web.

Resource Guide to Federal Funding for Technology in Education
http://www.ed.gov/Technology/funding.html

This site is maintained by the U.S. Department of Education and provides information on the Technology Literacy Challenge Fund, National Challenge Grants for Technology in Education, and other technology funding sources.

The Shoder Education Foundation, Inc.
http://www.shodor.org/

This research and education organization works to advance science and mathematics education through the use of modeling and simulation technologies. The site includes instructional resources and software ready to be used in the classroom.

Technology & Learning Online
http://www.techlearning.com/homepage.shtml

This online version of *Technology & Learning* magazine is for technology-using educators. It offers software reviews, tips on Web building, research in educational technology, and links to other sites.

Welcome to Mr. Lorenz's 7th Grade Math Page
http://www.hellgate.k12.mt.us/math/mathpg.htm

This is the Web page of John Lorenz, mathematics teacher at Hellgate Middle School in Missoula, Montana, and his students. Together, they designed online interactive mathematics activities, such as "The Birthday Problem," "The Apple Problem," and "Exploring Fermat's Last Theorem." This site is a good example of how students and teachers can use the interactive nature of the Internet to engage in cooperative and complex mathematical thinking.

Yahoo! Math and Science Education
http://www.yahoo.com/Education/Math_and_Science_Education/

This site provides many links to teaching resources, online math and science programs, and educational technology.

Organizations

ABLEDATA
The National Database of Assistive Technology Information
8455 Colesville Road, Suite 935
Silver Spring, MD 20910
(301) 608-8998
(800) 227-0216
TTY: (301) 608-8912
Fax: (301) 608-8958
http://www.abledata.com/index.htm

ABLEDATA is funded by the National Institute on Disability and Rehabilitation Research, a U.S. Department of Education affiliate. It maintains an electronic database of information on assistive technology and rehabilitation equipment available in the United States. Its Web site provides information and links pertaining to disability related resources.

Alaska Science and Technology Foundation
Suite 515
4500 Diplomacy Drive
Anchorage, AK 99508-5918
(907) 272-4333
Fax: (907) 274-6228
E-mail: info@astf.org
http://www.astf.org/

The Alaska Science and Technology Foundation gives grants to teachers of science and mathematics around the state of Alaska.

Alaska Society for Technology in Education (ASTE)
Contact: Jim Bennett
E-mail: jpb@kpbsd.k12.ak.us
http://akrac.k12.ak.us/ASTE.org/

ASTE is an affiliate of the International Society for Technology in Education which hosts an annual conference and maintains an online listserv. Volunteers from the educational community work to improve education through the use of information technologies.

Bureau of Education and Research
915 118th Avenue SE
P.O. Box 96068
Bellevue, WA 98009-9668
(425) 453-2121
Fax: (425) 453-1875
http://www.ber.org

This company sponsors national staff development training for educational professionals in the United States and Canada and offers several workshops on using technology in instruction, including calculators and geometric construction software.

Center for Gender Equity
Jo Sanders, Director
Washington Research Institute
150 Nickerson Street, Suite 305
Seattle, WA 98109
(206) 285-9317
Fax: (206) 285-1523
http://www.wri-edu.org/equity/temp.html

This organization promotes technology, science, and mathematics as careers and as areas of civic literacy among girls and women, primarily by strengthening the gender equity knowledge and skills of K-12 teachers and teacher-educators by producing projects, publications, and training.

Eisenhower National Clearinghouse for Mathematics and Science Education
Ohio State University
1929 Kenny Road
Columbus, OH 43210-1079
(614) 292-7784
(800) 621-5785
E-mail: info@enc.org
http://www.enc.org/

A nationally recognized information source for K-12 mathematics and science teachers is sponsored by the U.S. Department of Education. Resources include curriculum materials, a monthly list of outstanding Internet sites, lessons and activities, and links to other Web sites.

Equal Access to Software and Information (EASI)
P.O. Box 18928
Rochester, NY 14618
(716) 244-9065
E-mail: easi@educom.edu
http://www.rit.edu/~easi/

The EASI Web site includes information on online and onsite workshops; EASI's science, engineering, and mathematics project; and how to design accessible Web pages.

Idaho Department of Education Technology Services
http://www.sde.state.id.us/bocs/index.htm

This site contains information on educational technology, including the report, *Connections: A Statewide Plan for Technology in Idaho Public Schools.* Other information includes technology funding, Idaho's Technology Competency Examination Services, summer technology classes for educators at Boise State University, and other useful links.

Institute for Science, Math, and Technology Education
Office of Educational Partnerships
University of Washington
Box 351209
Seattle, WA 98195-1209
(206) 685-4745
Fax: (206) 616-7105
E-mail: k12inst@u.washington.edu
http://www.washington.edu/uwired/outreach/K-12

This program shares the expertise of the university community and resources with K-12 teachers and administrators throughout Washington state to create integrative, systemic approaches to science, mathematics, and technology education. The Institute also maintains a Web site with information and links to online resources related to science, mathematics, and technology education. Programs include: Teaching, Learning, and Technology, a certificate program for K-12 teachers; Science Education Partnership, a summer institute in research for middle and high school teachers; DO-IT, a residential summer program for high school students with disabilities who desire to pursue college and careers in science, engineering, mathematics, or technology; Mathematics, Engineering, Science Achievement (MESA) offering professional and curriculum development programs for teachers and other programs for middle and high school students; and University of Washington Engineered Biomaterials (UWEB), linking teachers with researchers to introduce biomaterials and related science concepts to K-12 students.

International Society for Technology in Education
1787 Agate Street
Eugene, OR 97403-1923
(541) 346-4414
Fax: (541) 346-5890
http://www.iste.org/

The society facilitates a network of K-12 teachers and administrators, enabling them to share classroom-proven solutions to the challenge of incorporating computers, the Internet, and other new technologies into schools.

Montana Office of Public Instruction
http://www.metnet.mt.gov/

Montana has established 15 regional training centers, interconnected by a state telecommunications network. The

Montana Educational Technology Network (METNET) facilitates the sharing of teaching resources among the centers through bulletin board systems that feature curriculum guides, lesson plans, and cooperative learning projects. This site also contains a link to the Montana Technology Plan (http://www.opi.mt.gov/OPI/Techplan.html)

The National Center to Improve Practice in Special Education Through Technology, Media and Materials (NCIP)
Education Development Center, Inc.
55 Chapel Street
Newton, MA 02158-1060
(617) 969-7100
http://www.edc.org/FSC/NCIP/

NCIP promotes the effective use of technology to enhance educational outcomes for students with sensory, cognitive, physical, and social/emotional disabilities. It also maintains an online network, NCIPnet, for teachers, parents, researchers, and others involved in working to improve education for children with disabilities. NCIP is funded by the U.S. Department of Education's Office for Special Education Programs.

National Council of Teachers of Mathematics (NCTM)
1906 Association Drive
Reston, VA 20191-1593
(703) 620-9840
http://www.nctm.org/

NCTM is a professional association dedicated to the improvement of mathematics education for all students in the United States and Canada. All NCTM members receive council publications including regular issues of the *News Bulletin, Student Math Notes*, and one or more of their four journals. The NCTM also publishes books, videotapes, software, and research reports.

National Educational Computing Association, Inc. (NECA)
University of Oregon/NECA
1244 Walnut Street, Suite A
University of Oregon
Eugene, OR 97403-2081
http://www.neccsite.org

NECA is an association of 15 professional societies interested in the role of computing in education. It also sponsors the annual National Educational Computing Conference.

National Science Teachers Association (NSTA)
1840 Wilson Boulevard
Arlington, VA 22201-3000
Fax: (703) 243-7177
http://www.nsta.org/

NSTA publishes five journals, a newspaper, many books, and a children's magazine, and conducts national and regional conventions.

Northwest Regional Educational Laboratory (NWREL)
101 S.W. Main Street, Suite 500
Portland, OR 97204-3297
(503) 275-9500
http://www.nwrel.org

NWREL provides leadership, expertise, and services to educators and others in the states of Alaska, Idaho, Montana, Oregon, and Washington. The Laboratory's online resource collection, The Library in the Sky (http://www.nwrel.org/sky), offers links to interactive mathematics and science programs, projects, lesson plans, discussion groups, and more. The following NWREL programs may be of particular assistance to teachers who use technology in mathematics and science instruction:

Equity Center provides equity training and technical assistance. The center conducts free workshops on equity in educational technology for school districts in Alaska, Idaho, Montana, Oregon, Washington, and the Pacific, including American Samoa, Guam, Hawaii, the Commonwealth of the Northern Mariana Islands, and the Trust Territory of the Pacific (Palau). A copy of *Closing the Equity Gap in Technology Access and Use: A Practical Guide for K-12 Educators* can be obtained from the center or an online version is available at http://www.netc.org/equity/.

Mathematics and Science Education Center provides K-12 teachers in Alaska, Idaho, Montana, Oregon, and Washington with resources and services to support challenging and effective mathematics and science curricula, instruction, and assessment for all students. The center's resource collection is a lending library of teacher support materials, assessment ideas, children's trade books, research syntheses, and videos. The center's publication, *Science and Mathematics for All Students: It's Just Good Teaching* provides equity teaching strategies. It can be obtained from the center or an online version is available at http://www.nwrel.org/msec/pub.html.

Northwest Educational Technology Consortium (NETC) provides information and services regarding technology in teaching and learning. Technology resources and information are available online at http://www.netc.org or from the NWREL home page, http://www.nwrel.org (select "Programs and Services" and then "Technology.") The technology resource librarian can respond to reference and information requests. E-mail requests can be directed to netc@nwrel.org or call (503) 275-9485.

Oregon Department of Education
Public Service Building
255 Capitol Street NE
Salem, OR 97310-0203
(503) 378-8004
Fax: (503) 272-7968
http://www.ode.state.or.us//technology/

This site offers technology education resources, including acceptable use policies, funding, and links to the Oregon Educational Technology Consortium (http://www.oetc.org/) and the Oregon Educational Technology Plan (http://www.ode.state.or.us//technology/techplan.htm).

Technical Educational Research Center (TERC)
2067 Massachusetts Avenue
Cambridge, MA 02140
(617) 547-0430
http://www.terc.edu

TERC conducts research and development in mathematics and science curriculum, teacher development, teaching and learning, and technology tools.

Washington Office of the Superintendent of Public Instruction
http://inform.ospi.wednet.edu/edtech/

This site provides information regarding educational technology and telecommunications in Washington state, including funding, discussion forums for educators, classroom activities, and the report, *Washington State Technology Plan for K-12 Common Schools* (http://inform.ospi.wednet.edu/edtech/summary.html).

Washington State Department of Information Services: Tech Central
E-mail: TechCentral@www.wa.gov
http://www.wa.gov/dis/k20topc/

This site describes Washington's K-20 Statewide Educational Telecommunications Network, a collaboration of public and private K-12 and higher education schools, state government, the legislature, and the private sector in providing distance learning and other lifelong learning opportunities. Includes a link to the *Washington State Technology Plan for K-12 Common Schools.*

Suppliers

The suppliers listed below offer a variety of materials and resources. While presence on this list does not imply endorsement by NWREL, the entries are representative of those available.

Apple Computers, Inc.
http://www.apple.com/education/

This site includes information about Apple Computer products and programs for education. A press release announcing the discontinuation of the Newton OS and the eMate, and Apple's plans to develop Mac OS-based portable computers is available at: http://www.apple.com/pr/library/1998/feb/27newton.html

Apple Office of Special Education
20525 Mariani Avenue
Cupertino, CA 95014
(800) 732-3131
http://www2.apple.com/disability/visual.html

This office provides an online database of assistive devices, software, networks, organizations, and publications concerning disabilities.

Broderbund Software, Inc.
http://www.broderbund.com/

This site provides information on the multimedia package, Kid Pix Studio.

ClarisWorks
http://www.claris.com/products/claris/clarisworksoffice/site/index.html

This Web site provides information on spreadsheet, word processing, and other applications.

Classroom Connect
431 Madrid Avenue
Torrance, CA 90501-1430
(800) 638-1639
http://www.classroom.com

Classroom Connect sells Internet products with supporting online resources for K-12 teachers, including Internet activities and projects, curriculum integration, professional development, guidelines for creating school Web pages, and acceptable use policies.

Hewlett Packard
http://www.hp.com/handheld/calculators/calculators.html

Provides information on Hewlett Packard's calculator products.

IBM National Support Center for Persons with Disabilities
P.O. Box 2150
Atlanta, GA 30301
(800) 426-4832
Fax: (800) 426-3395
TDD: (800) 426-4833
http://www.austin.ibm.com/sns/index.html

IBM's Independence Series offers assistive devices and software tools for people with vision, hearing, speech, mobility, and attention/memory disabilities.

Intelligent Peripheral Devices, Inc.
http://www.alphasmart.com

This site describes the features of the portable computer, AlphaSmart.

Key Curriculum Press
http://www.keypress.com

This site includes the pages, "The geometer's sketchpad: Geometry software for Euclidean, coordinate, transformational, analytic, and fractal geometry!" (http://www.keypress.com/product_info/sketchpad3.html) and "Geometry activities for middle school students with the geometer's sketchpad" (http://www.keypress.com/product_info/sketch_ms.html).

Pierian Spring Software
http://www.pierian.com

This site describes the spreadsheet application, Number Cruncher.

Robert Wagner Publishing, Inc.
http://www.hyperstudio.com/

This site describes the multimedia package, HyperStudio.

Sunburst Communications
http://www.sunburst.com/index.html

This site describes Sunburst's software and video products for grades preK-12.

Texas Instruments
http://www.ti.com

This site includes information on Texas Instruments' series of graphing calculators (http://www.ti.com/calc/docs/graph.htm) and information on its geometric construction software, Cabri Geometry II (http://www.ti.com/calc/docs/cabri.htm).

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