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ABSTRACT

This research brief highlights the role of mathematics in Advanced Technological Education (ATE) programs. In 1994, in response to an urgent national need for highly qualified technicians, the National Science Foundation established a major effort to support innovative programs in Advanced Technological Education, especially in the nation's community colleges. Mathematics, itself in the midst of a major reform effort, is an important but often overlooked component of virtually all ATE programs. This report highlights the role of mathematics in ATE programs by: (1) documenting the critical role that mathematics plays in science as well as engineering and technological education; (2) illustrating the important and challenging mathematics embedded in science, engineering and technological programs; (3) emphasizing the need to include high-level mathematics in ATE and similar programs; and (4) encouraging the kind of broad mathematics education that students will need to succeed in modern technological fields. This report is in two parts: analysis of the mathematics in selected science, engineering, and technological programs, and case studies of ATE program areas that are especially rich in mathematical potential. Analysis includes topics such as mathematics in the workplace and pitfalls to avoid. Case studies include Global Positioning Systems and Precision Agriculture. (JA)

AACC-RB-00-2

RESEARCH BRIEF

Why Math? Applications in Science, Engineering, and Technological Programs

By Susan L. Forman and Lynn Arthur Steen

In 1994, in response to an urgent national need for highly qualified technicians, the National Science Foundation (NSF) established a major effort to support innovative programs in Advanced Technological Education (ATE), especially in the nation's community colleges. Mathematics, itself in the midst of a major reform effort, is an important but often overlooked component of virtually all ATE programs. This report highlights the role of mathematics in ATE programs by:

- Documenting the critical role that mathematics plays in science as well as engineering and technological education.
- Illustrating the important and challenging mathematics embedded in science, engineering, and technological programs.
- Emphasizing the need to include high-level mathematics in ATE and similar programs.
- Encouraging the kind of broad mathematics education that students will need to succeed in modern technological fields.

THIS REPORT IS IN TWO PARTS: analysis of the mathematics in selected science, engineering, and technological programs, and case studies of ATE program areas that are especially rich in mathematical potential.

Analysis
- Mathematics in the Workplace
- Mathematics in ATE Programs
- Principles of Best Practice
- Pitfalls to Avoid
- Obstacles to Change
- Cautions

Case Studies
- Geographic Information Systems
- Global Positioning System
- Precision Agriculture
- High Performance Manufacturing
- Image Processing

Mathematics in the Workplace

Mathematics permeates the high performance workplace at every step, from planning and design to production processes and quality control. For example:

- A mechanic adjusting the tension of the belts attached to the drive shaft of a car or truck engine relies on geometric experience to determine how much play the belt has, to compare the play with specified tolerances, and to determine how much to adjust the drive mechanisms to bring the tension into the proper range.
- Anyone who assembles or repairs complex machinery must interpret in three dimensions information that is provided in two-dimensional illustrations such as exploded parts diagrams, blueprints, or computer assisted design (CAD) displays. "Seeing" three-dimensional arrangements in a two-dimensional illustration requires considerable geometric sophistication.
- Any retail business needs a system of inventory management to ensure that commonly requested items are readily available (either on the shelves or in nearby storage) while infrequently needed items are available by special order at a reasonable price. Determining the optimum balance between ordering in bulk and ordering individually involves not only careful cost accounting, but also mathematical modeling.
- Technicians in auto manufacturing facilities routinely prepare programs for computer numerical control (CNC) machine tools. A mistake in a program can cause a tool to crash into and destroy other equipment. Without a solid understanding of such issues as relative coordinate systems, it is easy for technicians to make expensive blunders.
- Elevators used to be programmed to take calls in the order in which they were received. Then came zoned systems, in which elevators are programmed to skip blocks of floors. Today's elevators use "fuzzy logic," which can balance multiple, sometimes conflicting, objectives. The latest trend is to use neural networks that "learn" from past traffic and move elevators in anticipation of requests. Salespeople, technicians, and building managers, among others, now need to think mathematically in order to understand how elevators operate.

Mathematics in ATE Programs

Programs supported by NSF's ATE initiative prepare students for careers in rapidly growing sectors of the economy that rely heavily on information technology. Mathematics plays a unique role here: always essential, but rarely central; always used, but rarely noticed. As everyone's concern, mathematics easily becomes no one's concern. To ensure a proper place for mathematics in ATE programs, program leaders must confront many issues, including these:

- Mathematics is rarely central to ATE curricular objectives. Projects generally set a mathematics requirement for students, but expect only that students meet the goals of the ATE courses.
- Mathematics is often taught in academic contexts that are disconnected from students' experiences, rather than in situations like those in which they will use mathematics.

- In order to accommodate different student skill levels, ATE course materials are mathematically uneven. Often their levels are based more on students' mathematical skills than on the mathematical potential of the ATE area.
- Many applications of mathematics are not well known, primarily because they are not part of the experience or working knowledge of mathematics faculty.
- Good mathematics often remains hidden. Because ATE projects generally focus on the operation of specialized software or protocols, much interesting mathematics lies invisible just beneath the surface of the application.
- Often it takes an experienced mathematician to detect aspects of programs that employ or could benefit from mathematical habits of mind. A better understanding of mathematics leads to better solutions.
- Mathematicians need to consult with practitioners in various science, engineering, and technological fields in order to understand and interpret the technology. Collaboration is essential.
- Even at institutions with funded ATE programs, there is relatively little interaction between mathematics and other faculty. Mathematics faculty are accustomed to teaching from a prescribed syllabus and resist opportunities (such as ATE projects) that may distract them from covering traditional skills and concepts.
- Most ATE programs rely on standard mathematics courses, such as college algebra, elementary statistics, and calculus, whose curricula and course structure are well established and have no relation to the kinds of applications found in ATE programs.

Principles of Best Practice

Effective science and engineering and technological programs incorporate high quality mathematical tasks that are authentic, intricate, interesting, and powerful.

AUTHENTIC TASKS:

- portray common contexts and honest problems
- employ realistic data, often including data that are incomplete or inconsistent
- meet the expectations of employers and other users of mathematics
- use realistic input and output, and avoid artificial worksheets
- reflect the integrity of both mathematics and the domain of application

INTRICATE TASKS:

- ask students to identify the right questions to ask
- require more than substitution into formulas
- employ multi-step procedures
- stimulate thinking that is cognitively complex
- confront students with incomplete or inconsistent information
- demonstrate the value of teamwork

INTERESTING TASKS:

- offer multiple means of approach
- touch on areas that are of interest to students
- appeal to a large number of students
- invite many variations and extensions
- provide horizontal linkages to diverse areas of life and work

- reflect professional guidelines from organizations such as the American Mathematical Association of Two-Year Colleges.

POWERFUL TASKS:

- connect graphical, numerical, symbolic, verbal, and technological approaches
- offer vertical integration from elementary ideas to advanced topics
- propel students to more advanced mathematics
- expand students' views of mathematics and its potential
- demonstrate the value of mathematics to the modern high performance workplace

Pedagogy

Effective teachers employ pedagogy that is active, student-centered, and contextual.

ACTIVE PEDAGOGY:

- encourages students to explore a variety of strategies
- stimulates discussion of available data in relation to what is being asked
- requires students to seek out the missing information needed to solve problems
- makes hands-on use of concrete materials

STUDENT-CENTERED PEDAGOGY:

- focuses on problems that students see as relevant and interesting
- helps students learn to work with others
- develops strong technical communication skills
- provides opportunities for students to use their own knowledge and experience

CONTEXTUAL PEDAGOGY:

- asks students to engage problems first in context, then with formal mathematics
- suggests resources that might provide additional information
- requires that students verify the reasonableness of solutions in the context of the original problem
- encourages students to see connections between mathematics and work and life
- clarifies the relationship between mathematics and its uses

Pitfalls to Avoid

Strong science, engineering, and technological programs go to great efforts to avoid some common pitfalls that can easily weaken students' mathematical experience. These pitfalls include:

- selecting tasks in order to cover specific topics, rather than to explore and solve interesting problems
- overlooking interesting or challenging mathematics that lies beneath the surface of many workplace tasks
- imposing unwarranted structure on a contextually rich problem in the interest of ensuring appropriate mathematical coverage
- believing that complex problems require sophisticated mathematics and that there is something wrong with solutions that use elementary techniques
- choosing problems that fail to help students prepare for higher achievement in mathematics

- presenting workplace tasks as if they are mathematics worksheets, thereby sterilizing the context of everything that makes the problem engaging
- sequencing the tasks in which mathematical activities are embedded in such a way that they lack conceptual continuity and limit students' intellectual growth
- failing to achieve mathematical closure (including concepts, vocabulary, methods, and generalizations) at the conclusion of an open-ended project
- not allowing students to reflect sufficiently on the process of mathematical modeling:

  —on accomplishments and limitations

  —on process and results

  —on opportunities and cautions

Obstacles to Change

Although it might seem obvious that mathematics should be a strong and tightly integrated component of every science, engineering, and technological program, many impediments make the construction of such a program surprisingly difficult in practice. These impediments are wide-ranging, starting with the traditional view of math held by mathematicians and nonmathematicians. Other impediments include:

- reluctance (even resentment) on the part of mathematics departments to be seen as "service" departments to other areas
- articulation agreements among two-year colleges and with transfer programs to four-year colleges
- hesitation of mathematics faculty to join in applied, interdisciplinary enterprises
- resistance of ATE and mathematics educators to collaborate because they lack a common purpose
- low status of applied programs in both schools and colleges
- difficulty finding authentic problems
- difficulty and time required to translate authentic problems to educational settings

Cautions

Experience shows that despite good intentions, a variety of problems can trip up even an enthusiastic instructor. Unless ATE and similar programs make a conscious effort to support strong mathematics, they may inadvertently widen the traditional skills gap between students aiming for a bachelor's degree and those seeking immediate career opportunities.

Because students tend to forget much of what they once learned in mathematics courses, there is a strong tendency to "dumb down" curricular materials to the level of what students remember rather than posing problems in their authentic context, regardless of the mathematical requirements.

Industry's expectation of graduates' mathematical level are often not those of mathematics teachers. For both financial and legal reasons, employers typically require workers in entry-level positions to have only the quantitative skills necessary to perform a job, and no more. Teachers, however, expect students to learn as much as possible to ensure strong preparation for further education. To succeed, ATE projects must serve both these goals, as well as specific industry purposes.

In some areas—accuracy, timeliness, clarity—industry expectations are typically much higher than those of the educational system. High performance work demands near-perfection, what industry calls "six sigma" standards. Unless ATE programs elevate students' internal standards to match those of industry, graduates may be unprepared for the requirements of modern employment.

Finally, mathematicians' ties to traditional courses pose a major impediment to the adoption of new courses. Even course titles such as "intermediate algebra"are so entrenched in curricular structures and articulation agreements that they will probably last forever.

Geographic Information Systems

Geographic Information Systems (GIS) integrate maps, charts, tables, and data into a coherent structure that is related logically, quantitatively, and spatially. Typically, such systems are used to organize and present information that has both geometric structure (such as maps, blueprints, and photographs) and quantitative structure (such as data about population, area, and density). GIS is widely used to display quantitative information for scientific research, public policymaking, and media presentations. It is an important tool for quantitative communication.

GIS implementations include:

- maps that show the location of streetlights in Los Angeles together with data about electrical circuits, operating costs, repair histories, and maintenance schedules
- three-dimensional orthophotographic views of lower Manhattan created for the New York Department of Environmental Protection to accurately represent potential building sites
- a study of how urbanization patterns affect the population of breeding birds in the Santa Monica mountains, based on linking GIS data using statistical packages such as S-Plus
- reduction of response times for 911 emergency service in Beaufort County, South Carolina, a rural region of islands, linked by bridges and ferries, that has a large transient population
- linking postal codes with customers' shopping patterns at different stores allows chains such as Best Buy and Target to ensure that inventory matches customer demand
- census data linked with urban, state, and national maps provide numerous and varied visual representations of the characteristics of the U. S. population
- analyses of satellite images of the same county over a 20-year period are used to determine changes in vegetation, urbanization, surface water, and other features important for regional planning

One of the applications of GIS with the largest potential benefit is its linkage with what is called "precision agriculture"—the integration of data on geographic position, soil conditions, crop yield, market prices, productivity, and other information to optimize farms' profit and yield.

Underlying Mathematics

Although mathematics underlies every aspect of GIS, most GIS software is designed to be used by people who know little mathematics. Virtually the entire content of school mathematics can be found embedded in activities based on GIS software:

- scaling figures and maps, students use ratio, proportion, similarity, perspective, and projection
- dealing with associated data, students use percentages, algebra, and elementary statistics
- relating data to spatial images, student use coordinate geometry in both two and three dimensions
- dealing with distances and areas, students convert between different coordinate systems and different units of measurement
- analyzing data (from, for example, population samples or satellite photographs), students use elementary functions to identify patterns in the data
- making maps, students use both raster (matrix) and vector (polygon) methods and convert from one to the other in the underlying database

However, sophisticated GIS software hides much of this good mathematics behind a facade of fascinating pictures. GIS provides an ideal vehicle to illustrate and apply an enormous variety of fundamental mathematical concepts and tools. With GIS, as with many computer-based implementations of mathematics, users who understand the underlying mathematics are able to imagine and execute more powerful ways to use these systems.

WEB SITES

GIS: Geographic Information Systems for the 21st Century (Indiana)

http://www.indstate.edu/geogis

CCITT: Community Colleges for Innovative Technology Transfer (California)

http://earth.fhda.edu

NCGIA: National Center for Geographic Information and Analysis (California)

http://www.ncgia.ucsb.edu

Global Positioning System

Global Positioning System (GPS) is a satellite-based system of signals that enables specially designed receivers to calculate precise positions on the surface of the earth. The satellite system, operated by the U.S. Department of Defense, became operational in 1995. Four satellites are located in each of six circular high-altitude (20,000 km) orbits spaced 60 degrees apart and inclined at 55 degrees from the equator. Each satellite has a period of 12 hours and transmits its position and the exact time on two radio frequencies. Typically, four or five satellites are visible at any time from any point on the surface of the earth.

Handheld battery-powered receivers, now widely available, use signals from the satellites to calculate the receiver's three coordinates: latitude, longitude, and altitude. A marvel of engineering and mathematics, GPS is now widely used for business (in agriculture, surveying, and transportation), emergencies (for 911 calls and other rescue operations), travel by car, and recreation (by motorists, boaters, and hikers).

Some uses of GPS require the data from only one location, which can then be transferred to a map to identify the receiver's position. Other applications (for example, in precision agriculture) involve using data from many different points to construct a map or to feed information to a Geographic Information System (GIS), in which the position data are related to other information. Typical receivers also indicate the positions (altitude, azimuth, and identification number) of the satellites from which signals are being received, so GPS receivers can also be used to identify and track the satellites.

Examples of Use

GPS systems are used to track anything that moves—from freight trains to airplanes, from tractors to yachts. Farmers use GPS to link geographic information with soil analysis and crop yield; airlines are beginning to use it to guide planes; and freight companies use it to track cargo across the country.

- GPS data relayed from moving trains and trucks help dispatchers track freight as it moves across the country, letting customers plan for deliveries with precision. This system also helps reduce theft of valuable freight.
- Wilderness hikers use GPS receivers to monitor their positions, which they can then plot on a map. Before GPS, hikers would determine location by taking compass readings to distant landmarks and marking the readings on a map to find the point of intersection.
- GPS receivers can record a limited amount of data associated with each position, so surveyors who wants to mark the locations of trees, bushes, and other natural features on a plot of land can record the locations while carrying a GPS receiver around a property.

GPS receivers provide a means of displaying latitude and longitude, information that is not normally evident. Experience with GPS can help students understand the changes in latitude and longitude that correspond to more routine measurements such as kilometers and miles (or feet and yards). Data recorded from a stationary GPS receiver quickly reveal a pattern of random errors that can be used to determine the reliability of the information.

Underlying Mathematics

All GPS activities—from decoding satellite signals to locating the satellites themselves, from interpreting GPS data to creating specialized maps—build on a substantial base of mathematics, especially geometry and statistics. The system itself involves the three-dimensional geometry of the surface of the earth and the orbits of the GPS satellites. Translating three-dimensional data into two-dimensional maps involves making many choices of projection and interpolation. Wise use of the system also requires a thorough understanding of the limitations of its accuracy and of strategies for reducing variability.

If there were no sources of error, a receiver's position could be calculated by simple algebra and spherical trigonometry from two satellite signals.

WEB SITES

GIS, GPS, and Remote Sensing Departments, Brevard Community College, Palm Bay Campus (Florida)

http://www.brevard.cc.fl.us/palmbay/pbpg622.html

Global Positioning System Overview (Colorado)

http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html

The GPS Resource Library

http://www.gpsy.com/gpsinfo

Terrain Analysis Home Page, Hunter College Department of Geography (New York)

http://everest.hunter.cuny.edu/terrain/index.html

Trimble GPS (California)

http://www.trimble.com

The distance of the receiver from each satellite is determined by the time it takes the signal to travel from the satellite to the receiver. Two such distances, measured from different satellites, are sufficient to determine the position of the receiver on the two-dimensional surface of the earth; distances measured from three satellites give enough data to calculate altitude as well.

This calculation, called "trilateration," is akin to triangulation except that it uses the lengths of three lines (rather than the angles from three points) to locate the receiver. Mathematically, it involves solving three simultaneous equations that are based on the Pythagorean formula in three dimensions. It also requires knowledge of conversion factors to transform the satellite information into actual latitude, longitude, and altitude. These calculations are within the scope of standard algebra and geometry courses—and within the capabilities of a computer chip.

Precision Agriculture

Computer tools such as spreadsheet programs and technology such as Global Positioning Systems (GPS) have begun to transform agriculture to a precision, high-performance industry where data are used to minimize costs and optimize yields. Farmers use tractor-mounted GPS receivers to record location when they take soil chemistry readings and when they apply fertilizer and herbicides. In precision agriculture, these GPS data are then combined with other data such as pH, moisture content, weed density, and crop yield in a computer spreadsheet or Geographic Information System (GIS).

Careful use of such data, combined with comparison information from other farms and earlier years, lets farmers minimize waste and optimize yield. GPS receivers and associated computer equipment cost about $20,000, which is cost-effective for farmers who use it for 1,000 acres or more.

Data gathered from a tractor-mounted GPS receiver can be used to create a map of a farm (in vector or raster form) that is linked by means of a GIS program to a database containing spatial or thematic information. This information can then be used to create thematic maps for soil type, pH, potash, organic matter, weeds, and yield.

Using data on yield gathered from previous years or from databanks of information on similar farms, GIS can be used to prepare "prescription maps" of fields that indicate how much fertilizer, herbicide, and water is needed in each small patch of land. Additional soil analysis combined with market information about predicted crop prices can help farmers make wise decisions about crop rotation and planting schedules. Regular use of such systems can optimize crop yield and minimize costs, thus increasing the chance for profit.

Supporting Mathematics

To use GPS information most effectively, farmers must combine it with data collected on the ground, then convert the data into topical (or thematic) maps that display the variation of yield, moisture, soil pH, and other relevant factors. This task—converting discrete data into continuous maps—is the opposite of what is normally taught in mathematics courses. Instead of calculating data points from formulas, GPS receivers provide the data points and farmers determine the graphs that most accurately represent the data. This technique, called "surface analysis," involves constructing topographic maps from isolated data points. Depending on the goal (crop yield, moisture conservation), there are many possible algorithms that can be used for this process.

Because farmers need GPS data that are more accurate than the normal range of 50–100 meters provided by standard receivers, they rely on supplementary data from ground-based stations that transmit estimates of the current error from satellite signals in that region. By combining this information with that from the GPS satellites—using the error as a new unknown and adding data from a fourth satellite—tractor-based GPS receivers can calculate position to within approximately 8–10 meters.

Sophisticated use of GPS and GIS data also requires some information, however tentative, on market conditions for various possible crops. With these data, optimization tools such as linear programming can be used to help decide how much of which crop to plant on which field in order to maximize profit.

The ATE Center at Hawkeye Community College in Iowa is developing a school curriculum to support this new quantitative approach to agriculture. Most of this curriculum is mathematical:

- Grades K–5: Latitude, longitude, spatial concepts, data collection; maps, GPS receivers, basic mathematics and computing

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- Grades 6–8: Spatial concepts, data collection, data analysis, algebra, more GPS experience, thematic maps
- Grades 9–12: Data analysis, decision making, algebra, geometry, advanced thematic mapping.

These quantitative themes support applications in agriculture, horticulture, natural resources, and animal science.

WEB SITES

NESPAL: National Environmentally Sound Production Agriculture Laboratory:

Precision Agriculture Resources (Georgia)

http://nespal.cpes.peachnet.edu/home/links/pa/default.asp

Precision Agriculture Technology, Hawkeye Community College (Iowa)

http://www.ag.hawkeye.cc.ia.us/PrecisAg.htm

Agriculture Online (Iowa)

http://www.agriculture.com

High Performance Manufacturing

Today's internationally competitive manufacturing requires both high performance and rapid responsiveness. Customers expect products to be free of flaws, and marketplace innovation quickly makes products obsolete. Production processes must be highly efficient, yet be thoroughly revamped every year or two.

Mathematical and statistical methods aid manufacturing in many ways:

- Statistical analysis transforms data gathered from manufacturing processes to forms that are meaningful for process and quality control.
- Mathematical modeling translates manufacturing problems into quantitative forms that are suitable for analysis by computer methods.

Such methods assist in the design of materials (such as high-strength ceramics and polymeric systems), in manufacturing processes (such as crystal growth, molding, joining, curing, and coating), and in the evolution of manufacturing methods (such as solid modeling, rapid prototyping, and molecular manufacturing). Mathematical methods are also used widely in management decision-making in manufacturing.

Underlying Mathematics

"Six sigma," developed more than a decade ago at Motorola, is a statistical quality control method that is said to combine "the art of the efficiency expert with the science of the computer geek." The term refers to the infinitesimally tiny number of errors (one in a billion) found six standard deviations from the average in a normal error curve. Of course, no company can really achieve that kind of perfection. But like a religion, six sigma offers an ideal state toward which adherents continually strive. Big no-nonsense companies like Allied Signal, Motorola, and General Electric swear by it. Six sigma has galvanized General Electric more than anything else in 40 years, according to GE chairman John F. Welch.

To achieve six sigma reliability, a company breaks a customer's requirements into individual steps and then, based on how the systems interact, sets optimum specifications for each step to achieve the desired result. For example, if a customer wants to be billed on the same day each month, each step in the process (for example, information transmission to billing, delays in mailing room) is analyzed to set performance specifications and provide back-up for inevitable contingencies such as employee illness and equipment breakdown. Managers like six sigma because it promotes teamwork across the organization.

Techniques like six sigma are among the new manufacturing strategies promoted by the Advanced Integrated Manufacturing (AIM) Center in Dayton, Ohio. A partnership between Sinclair Community College and the University of Dayton, AIM is a customer-driven developer and provider of professional and educational services whose mission is to help companies implement advanced manufacturing technologies, processes, and techniques. The AIM Center is supported by the ATE program to serve as a national center for developing interdisciplinary curriculum materials for an associate degree in manufacturing engineering technology, and for providing substantial faculty development opportunities. Two examples of the center's recent work illustrate the relevance of mathematical thinking to manufacturing processes:

- Whiteford Foods in Ohio produces more than one million frozen beef patties a day. The logistics of packaging and shipping the product had become a nightmare, so with the assistance of the nearby AIM Center, Whiteford developed a just-in-time inventory system for all the dry goods (spacing paper, plastic bags, shipping cartons) used in the manufacturing process. The center then helped Whiteford develop a plan for placing equipment and channeling product flow in a more productive fashion. The result was a 50 percent decrease in the time required to move products along the various stages of the production process.
- McCauley Propeller Systems, a manufacturer of airplane propellers, designed a new production facility that more than doubled productivity and reduced waste by more than 60 percent. They did this through a program that involved creating computer simulations of various assembly line layouts and options, then using a full-scale mock-up to test the simulations in a realistic work environment. A one-week workshop organized by the AIM Center introduced McCauley production workers to modern manufacturing concepts and let them work in the mock assembly room to suggest improvements.

Some of the mathematical know-how used to improve manufacturing processes pertains to production techniques such as measurement, calculation, alignment, and determining tolerances. Other aspects pertain to quality control tasks such as sampling, estimating errors, and creating and using quality control charts. Still others pertain to managing the production process, including tasks such as scheduling and inventory control. The underlying mathematics involves topics in algebra (simultaneous equations), geometry (indirect measurement), finite mathematics (linear programming), and calculus (optimization).

WEB SITES

AIM: Advanced Integrated Manufacturing Center (Ohio)

http://www.aimcenter.org/

Wisconsin Manufacturing Curriculum Center (Wisconsin)

http://www.techspan.net/

Measure Up: Dimensional Metrology and ISO 9001
Madison Area Technical College (Wisconsin)

http://td.ele.madison.tec.wi.us/~metal/metal.htm

SCANS 2000: The Workforce Skills Website

http://www.scans.jhu.edu

Distinctive Manufacturing Technology, Oklahoma State University at Okmulgee (Oklahoma)

http://www.osu-okmulgee.edu/nsf/nsf.htm

Materials Aspects of Manufacturing Technology (Washington)

http://depts.washington.edu/mtl

Image Processing

"Image processing" is a broad term for representing and analyzing data in visual form. More narrowly, it means manipulating the numeric data in a digital image to enhance the image's appearance. Through image processing, faded pictures can be restored, medical images clarified, and satellite photographs calibrated. Image processing software can also translate numeric information into images that can be edited, enhanced, filtered, or animated in order to reveal relationships previously not apparent. "Image analysis," in contrast, involves collecting, analyzing, and transforming measurement data from digital images. Image analysis provides an accurate digital substitute for rulers and calipers.

Originally developed for space exploration and biomedicine, digital image processing and analysis are now used in a wide range of industrial, artistic, and educational applications. Software for image processing and analysis is widely available on all major computer platforms. This software supports the modern adage that "a picture is worth a thousand words, but an image is worth a thousand pictures." Image processing is used widely in many fields, including beotechnology, evironmental science, art, and medicine

BIOTECHNOLOGY

- automate DNA sequencing
- analyze electrophoretic gels
- analyze polymerase chain reaction
- automatically analyze petri dish colonies
- represent proteins visually
- design drugs

ENVIRONMENTAL SCIENCE

- monitor weather patterns
- enhance images from underwater photography
- determine water flow from satellite photography

ART

- create digital images for films
- modify photographs for advertising
- enhance architectural drawings

MEDICINE

- analyze the morphology of tissue sections
- clarify mammograms, X rays, MRI, PET, and other images
- represent human anatomy, as in the National Library of Medicine's Visible Human project
- perform digital dissection
- compare DNA images for clinical or forensic research

Satellite photographs of developing storms are readily available on the Internet and provide excellent source material for learning the potential uses of image processing. By taking measurements from a sequence of satellite images of a developing hurricane and combining these data with other meteorological data (for example, the position of the jet stream and the position and barometric strength of high- and low-pressure cells), students can track hurricanes as they develop and predict the time and location of landfall. It is not uncommon for student predictions to be almost as accurate as those of professional forecasters.

In order to properly interpret electrocardiogram graphs, emergency medical technicians (EMTs) need to understand the relation between the electrical and mechanical actions of the heart. Image analysis software offers students who are training for EMT certification an invaluable link between the physiology of the heart and the abstract graphs associated with the heart's electrical activity. By seeing graphical information alongside slow-motion images of a beating heart, students can learn to "read" the graphs—a skill they will need when dealing with patients.

Image processing software provides a natural context for students in the middle grades to learn about measurement, geometry, ratio, slopes, percentages, histograms, and simple equations. Images of the United States with state outlines overlaid on satellite images provide a rich resource for exercises in measurement and area. A CAT scan of an emphysema patient's lungs provides a realistic context for learning about ratios, percents, and decimals. And the process of image processing itself provides opportunities for students to "see" the impact of different histograms, which can represent scaling changes used to improve the visualization of image data.

Other instructional uses of image processing include:

- displaying the significance of small units of measurement (such as millimeters and microns) by using magnified images of small bugs, mites, and cells

- creating a "typical" face by averaging the pixels from a number of scanned pictures
- morphing one picture into another using linear transitions between corresponding pixels
- measuring angles and distances in handwriting samples to detect forgeries
- measuring key sports data from video images of baseball hitters, tennis servers, and basketball free-throw shooters

WEB SITES

CIPE: Center for Image Processing in Education (Arizona)

http://www.evisual.org

ESRI: Environmental Systems Research Institute, Inc. (California)

http://www.esri.com

BASIS: Berry and Associates Spatial Information Systems (Colorado)

http://www.innovativegis.com/basis

Supporting Mathematics

A digital image is a matrix of measurements (of light, temperature, altitude, or some other quantity) sampled at regular intervals, rounded off to integers, and displayed according to a scale that translates integer values into pixels of specific colors or shades of gray. In a computer, a digital image is a long string of numbers representing rows of pixels of different colors or brightness. The data that create a digital image can be exported to (or imported from) a spreadsheet, where they can be manipulated with standard mathematical tools.

Digital image processing is an inherently mathematical process. Every action performed by image processing software involves one or more mathematical transformations of the digital data. These transformations include resizing, density slicing, measuring (distances and angles), scaling, and stacking. Many of these transformations are linear, but some, such as enhancing edge effects, are nonlinear. Image processing software lets an investigator work in many different modes—entirely visually, with graphs of the associated mathematical transformations, or with the actual underlying data.

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ATE Centers of Excellence

ATEEC: Advanced Technology Environmental Education Center (Iowa)
http://www.ateec.org

Bio-Link: National Advanced Technological Education Center for Biotechnology (California)
http://www.bio-link.org

MATE Center: Maricopa Advanced Technology Education Center (Arizona)
http://matec.org

MATEC: Marine Advanced Technology Education Center (California)
http://www.marinetech.org

NCTT: Northeast Center for Telecommunications Technologies (Massachusetts)
http://www.nctt.org

NJCATE: New Jersey Center for Advanced Technological Education (New Jersey)
http://www.njcate.org

NCEAME: National Center of Excellence for Advanced Manufacturing Education (Ohio)
http://www.erinet.com/dwolf/pages/nceame/nceame.htm

NCSR: Northwest Center for Sustainable Resources (Oregon)
http://www.nscr.org

NWCET: Northwest Center for Emerging Technologies (Washington)
http://www.nwcet.org

SCATE: South Carolina Advanced Technological Education Center (South Carolina)
http://scate.org

SCATE: Southwest Consortium for the Advancement of Technology in Education (Texas)
http://www.scate.net

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