

# A Vision: Mathematics for the Emerging Technologies

## A Report from the Project Technical Mathematics for Tomorrow: Recommendations and Exemplary Programs

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# Preface

Over 80 people participated May 12–15, 2002 in a national conference to create a vision for the mathematics for the emerging technologies. The meeting was held at the San Rémo Casino and Resort, Las Vegas, Nevada under the auspices of a National Science Foundation funded grant “Technical Mathematics for Tomorrow: Recommendations and Exemplary Programs” (DUE #0003065) that was awarded to the American Mathematics Association of Two-Year Colleges (AMATYC).

The tone for the meeting was established during the opening session when Project Director Mary Ann Hovis said,

The purpose of this conference is to identify and promote exemplary practices and use them as a basis for developing a vision and making recommendations for mathematics programs which serve students in highly technical curricula, such as biotechnology, computerized manufacturing, electronics, information technology, semiconductors, and telecommunications.

Participants in the conference included mathematics educators, technical personnel from business and industry, and technical faculty from two-year colleges. A complete list of participants is on pages 31–34.

Preliminary work on the vision was done during two CRAFTY<sup>1</sup> CRAFTY workshops in October 2000. The CRAFTY workshops were part of AMATYC’s NSF-funded grant. They were patterned after, and done in collaboration with, a series of workshops conducted by the CRAFTY subcommittee of the Committee on the Undergraduate Programs in Mathematics (CUPM) of the Mathematical Association of America (MAA). Participants in the CRAFTY workshops are listed on pages 35–38.

The CRAFTY workshops were held in discipline areas served by mathematics, and the CRAFTY reports attempt to describe to mathematics faculty what skills should be developed by the mathematics curriculum during the first two years of college.

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<sup>1</sup>Originally, CRAFTY was an acronym for **C**alculus **R**eform **A**nd the **F**irst **T**wo **Y**ears. At its January 2002 meeting, CRAFTY elected to rename itself as the Subcommittee on **C**urriculum **R**enewal **A**cross the **F**irst **T**wo **Y**ears.

Project and CRAFTY web pages	<p>At AMATYC’s CRAFTY workshops, technicians used a set of questions developed by the MAA to address the mathematics needs of employees and/or students in the emerging technology areas of biotechnology; electronic engineering technology, semiconductors, and telecommunications; information technology; and mechanical and manufacturing technology. Copies of these reports can be downloaded from the <a href="#">AMATYC web page</a> or the <a href="#">project web page</a>.</p> <p>The <a href="#">CRAFTY web page</a> contains information about CRAFTY and links to all the workshop reports. Additional information as well as links to CRAFTY articles that have appeared in MAA’s newsletter <i>Focus</i> can be found at <a href="#">Focus web page</a>.</p> <p>The national conference began with a keynote presentation on “Community Colleges, Technology, and Economic Opportunity: What’s Next in the New Economy” by Robert Templin, Senior Fellow at the Morino Institute in Reston, Virginia.</p>
Advisory Committee	<p>The Project had an Advisory Committee of seven members. The names and brief biographies of Advisory Committee members are on pages 39–40. The Advisory Committee first met in January 2001 and established criteria for selecting exemplary programs. In May 2001, the Project’s National Advisory Committee selected ten programs it deemed exemplary in one or more aspects.</p>
Exemplary programs	<p>Each of the exemplary programs was honored at the conference. Representatives from seven of the programs were able to attend, and each gave a short focused presentation on one aspect of his or her school’s program. These presentations and the abstracts that were in the conference materials provided participants with examples they could use in developing the vision.</p>
National conference	<p>The preliminary part of the conference concluded with presentations by representatives from each of the emerging technology areas that were the basis of the CRAFTY meetings in October 2000. These talks provided a synopsis of the thinking by the technology groups. Participants were also given the latest versions of the CRAFTY reports.</p> <p>For the majority of the conference, participants outlined a vision for the mathematics needed in emerging technologies. Each participant was placed in one of six groups, and each group had a representative from at least three of the CRAFTY areas, a member of the Advisory Committee, and at least one representative from an exemplary program. The rest of the people in the groups were mathematics educators.</p> <p>The groups were led by Facilitators and Recorders, listed on page 34, who were chosen by the project investigators. The Facilitators and Recorders met prior to the conference to establish goals for their groups, examine the proposed deliverables, and discuss general procedures.</p> <p>One of the deliverables was a set of six matrices. Each group was given a set of skeleton matrices to use as discussion guides. Information from all the matrices was consolidated for this report and helped to define the vision for the mathematical needs of students in emerging</p>

technologies. In addition, participants generated a set of recommendations for additional activities.

This Vision is being distributed to all two-year colleges, all AMATYC members, and all participants in the CRAFTY workshops or the national conference.

Many people worked to produce this report. Representatives from business and industry and faculty from the technologies gave of their time to contribute to the Vision. The Advisory Committee was always prepared for our meetings and had many excellent suggestions that made the project more successful. George Vaughn, the Project evaluator, gave us many helpful suggestions on how to improve the questionnaires.

The AMATYC leadership and office staff, especially President Susan S. Wood, who initiated the proposal for this project, Treasurer Ilga Ross, and Accounting Director Christy Hunsucker were instrumental in the success of the project. We are also grateful for the support of the current AMATYC President, Philip Mahler, the AMATYC officers, and other members of AMATYC's office staff who gave us their support.

The project's investigators would also like to thank all the participants in the CRAFTY workshops and the national conference for their hard work and patience. The Facilitators and Recorders at the national conference were asked to do project work before, during, and after the conference. We are especially grateful for their efforts.

This project was interrupted by the events of September 11, 2001. The conference was scheduled for the weekend after those events, and, of course, had to be postponed. Most participants stayed with the project and attended the 2002 conference. The schedule change did, however, prevent three of the exemplary programs from sending representatives to the conference.

It is also appropriate to thank the hotel staff of the San Rémo for allowing AMATYC to cancel the scheduled room block and reschedule the events without penalty.

Note: All supporting documentation for this vision statement—the matrices, abstracts of the exemplary programs, CRAFTY reports—can be downloaded from the [AMATYC web page](#) or the [project web page](#).

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# A Vision: Mathematics for the Emerging Technologies

A national conference to establish a vision for the mathematical needs of students in emerging technologies was held as part of an NSF-funded grant “Technical Mathematics for Tomorrow: Recommendations and Exemplary Programs” awarded to the American Mathematics Association of Two-Year Colleges (AMATYC). Participants included mathematics educators, technical personnel from business and industry, and technical faculty from two-year colleges. This Vision document is the result of that conference.

## Introduction

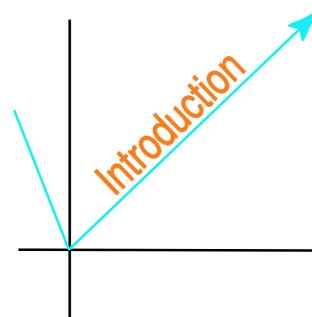
Preliminary work on the vision was done during two CRAFTY<sup>2</sup> workshops in October 2000. The CRAFTY workshops were part of AMATYC’s NSF-funded grant and were patterned after, and done in collaboration with, a series of workshops conducted by the CRAFTY subcommittee of the Committee on the Undergraduate Programs in Mathematics (CUPM) of the Mathematical Association of America (MAA). The CRAFTY workshops were held in discipline areas served by mathematics and the CRAFTY reports attempt to describe to mathematics faculty what skills should be developed by the mathematics curriculum during the first two years of college.

At AMATYC’s CRAFTY workshops, technicians used a set of questions developed by MAA to address the mathematics needs of employees and/or students in the emerging technology areas of biotechnology; electronic engineering technology, semiconductors, and telecommunications; information technology; and mechanical and manufacturing technology.

The NSF Project had an Advisory Committee of seven members. The Advisory Committee first met in January 2001 and established criteria for selecting exemplary programs. In May 2001, the Advisory Committee selected ten programs that it deemed exemplary in one or

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<sup>2</sup>Originally, CRAFTY was an acronym for **C**alculus **R**eform **A**nd the **F**irst **T**wo **Y**ears. At its January 2002 meeting, CRAFTY elected to rename itself as the Subcommittee on **C**urriculum **R**enewal **A**cross the **F**irst **T**wo **Y**ears.



more aspects. Input from the exemplary programs and the CRAFTY reports formed a basis for the dialogue on issues surrounding the mathematics needs of students in emerging technologies.

Issues discussed included

- the integration of mathematics content with science and technology;
- the balance between abstract and applied mathematics;
- pedagogy;
- the use of technology;
- prerequisite skills;
- the nature of ongoing professional development for faculty teaching technical mathematics;
- connections among mathematics faculty, technical program faculty, business and industry; and
- transferability of the mathematics courses for students in emerging technologies.

**Students must acquire a set of “soft skills” that prepare them for the workplace.**

In order for students, especially those preparing to become technicians, to be prepared for the workplace, they must acquire a set of “soft skills” that are often referred to as SCANS skills.<sup>3</sup> These skills must be developed by a coordinated effort among all faculty.

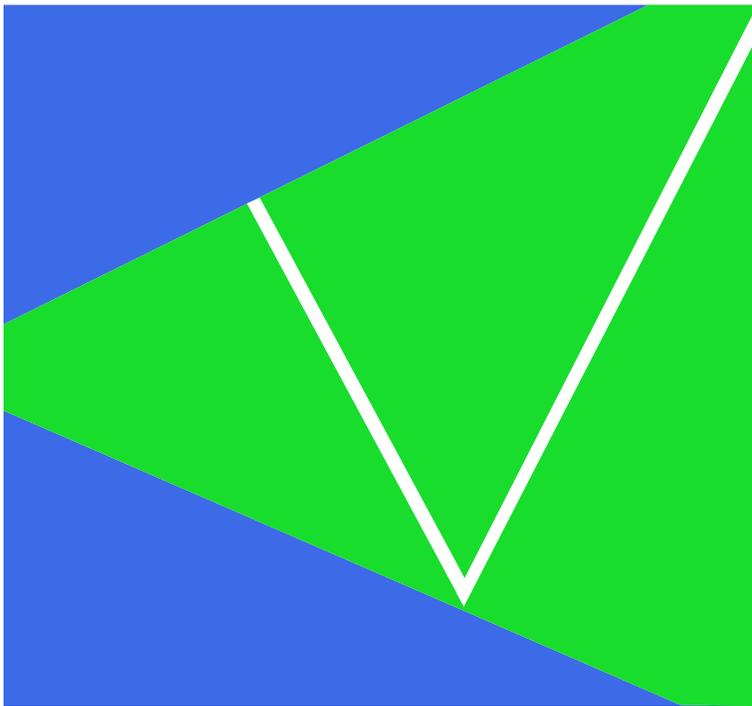
As mentioned in the Preface, participants were formed into six groups. Each group had at least one person from each three of the CRAFTY areas and one or more representative from an exemplary program. Except for the members of the Project’s Advisory Committee, the rest of the people in each group were mathematics educators.

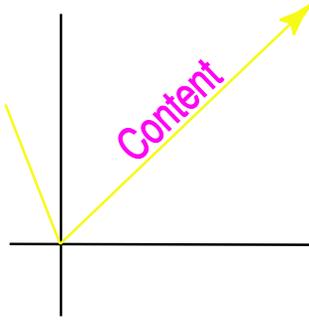
Each group was given a skeleton matrix to use as a guide for the discussion during the breakout sessions. The six breakout sessions were in the areas of (a) Content, (b) Pedagogy and Classroom Environment, (c) Delivery, (d) Currency, (e) Successful Programs, and (f) Other Recommendations.

During the conference, participants decided that the Delivery matrix was not needed and that more time should be devoted to resources, including the classroom environment. Several of the groups also created lists of recommendations of further efforts that AMATYC, NSF, and/or the project staff should consider pursuing.

<sup>3</sup>SCANS is the acronym for the Secretary’s Commission on Achieving Necessary Skills. Ten years ago, this commission of 31 senior Human Resource executives and educators and union officials issued two reports, entitled: *What Work Requires of Schools* and *Learning a Living*. The so-called SCANS skills include the ability to use basic and advanced skills, such as mathematics and problem-solving to solve problems in five domains. The two math-intensive SCANS problem domains are planning and systems.

The matrices each group completed were merged into the six composite matrices that were used to develop this vision of the mathematics needs of students in emerging technologies.





## Content

The discussion of the Content recommendations begins with three concepts that span the entire mathematics curriculum: critical thinking, problem solving, and communicating mathematically. The discussion of these three areas is followed by recommendations in the more specific areas of arithmetic, algebra, geometry, trigonometry, statistics, calculus, etc.

### Critical Thinking, Problem Solving, and Communicating Mathematically

Perhaps the most important aspect of the Content recommendations was the general ideas of critical thinking, problem solving, and communicating mathematically. In fact, as one group said, “Critical thinking, problem solving, and communicating mathematically, while containing content objectives of their own, can and should be taught through all of the other topics listed.”

Because of the need to communicate with co-workers, technicians need to give both written and oral presentations and should be able to explain (and interpret) mathematical ideas using the “Rule of 4”—that is, they need to be able to understand and use mathematics with formulas, graphs, and tables, and they need to communicate this understanding. Even though the Rule of 4 is not a new concept (it was the foundation of much of the “reform” mathematics in the 1990s), the groups deemed it important enough to warrant special consideration and mention.

Students in ATE (the National Science Foundation’s Advanced Technological Education) programs should be able to select an appropriate method to solve a problem. In the participants’ view, a problem is not just a traditional “story” problem.

There are different levels of problems. Some problems require students to do some research, develop their own process, collect data, or use technology to organize data. Bloom’s taxonomy (see pages 27–29) was mentioned several times during the meetings. While Bloom’s taxonomy is some 40 years old, participants felt that it was still appropriate. In particular, in mathematics courses for students in emerging technologies, students should be given, and be able to handle, problems from all six levels of Bloom’s taxonomy.

Problem solving also requires that students know some logic. Students should begin their program of study with the ability to use inductive and deductive reasoning. When placed in the context of the mathematics that students are studying, deductive reasoning is not the type of formal proof often encountered in mathematics courses, but rather the ability to form arguments or solve problems based on laws, rules, or other widely accepted mathematical principles.

**Critical thinking, problem solving, and communicating mathematically should be taught through all mathematics.**

**Technicians need to give both written and oral presentations.**

**Students should be able to handle problems from all six levels of Bloom’s taxonomy.**

Problem solving means that students must learn how to extract the relevant information from a problem, identify what, if any, additional information is needed, develop a plan, solve the problem, check the reasonableness and accuracy of the solution, present their findings orally using appropriate visuals (spreadsheets, presentation software, animation, etc.), and submit a written report.

Word problems should often involve “real-life” situations in a student’s field of study. Using “real-life” situations is often difficult because many schools do not have enough students in any one program to allow for a mathematics course devoted to its students.

It is essential that students learn to use estimation skills to assess the reasonableness of answers. While estimation skills have always been important in mathematics, many students today rely on an answer produced by a calculator or computer. Estimation skills are needed so students can determine if they have obtained a reasonable answer.

Dimensional analysis is a universal concept that was stressed by participants. Technical faculty stressed the importance of using examples which require units and conversion between units. Dimensional analysis should get increased emphasis.

As mentioned above, students need to be able to communicate mathematically. Because technicians need to explain a problem, process, or solution to their colleagues, clients, or supervisors, increased emphasis must be given to strengthening student skills in communicating mathematically.

Mathematical communication involves more than explanations. It also means that technicians need to be able to read and understand mathematics expressed through tables, graphs, formulas, and written statements. They also need to be able to translate among these formats.

## Arithmetic

Most people do not normally consider arithmetic to be a college-level topic, which may explain why it did not get much attention from participants. The arithmetic topics that need the most attention are measurement conversions (metric-English, English-metric, Celsius-Fahrenheit), ratio, proportion, and scientific and engineering notation.

Many students have probably not seen engineering notation before they started technician training. While they should have been exposed to scientific notation when they were in secondary school, it probably did not get much emphasis unless they took physics or chemistry.

Students should know how to compute with percents. This topic was undoubtedly taught several times during their middle school years, but it is an area where most students do not perform well.

Some areas, such as information technology (IT), need a topic that was popular during the “modern math” era: number base conversions. While information technology students will be taught, and use, the binary, hexadecimal, octal, and decimal systems in their IT courses,

**It is essential that students learn to use estimation skills.**

**Estimation skills and dimensional analysis are universal concepts.**

**Arithmetic topics that need the most attention are measurement conversions, ratio, proportion, and scientific and engineering notation.**

it is an arithmetic topic that might be included in some mathematics courses for students in emerging technologies.

### Algebra

When they enter college, students should already have the ability to apply the basic operations of signed numbers, algebraic operations, algebraic properties, and basic graphing. They should be able to solve linear equations in one variable and  $2 \times 2$  systems of linear equations. At present, many students entering college do not have these abilities or cannot apply these skills in a context outside the mathematics class.

The ability to apply mathematics topics outside of mathematics, or in a new setting, is vital. Mathematics educators must construct curricula that require students to make connections among mathematics topics and with applications from several technical areas. Students need to internalize basic algebra concepts so that when they see these concepts in an application, the procedures are second nature.

Modeling with functions is the primary algebra topic that participants thought students need to learn. This area has received increased attention in the past few years. Modeling and problem solving could almost be considered as natural partners and modeling fits quite logically with the goal to use realistic data.

Students have long been *given* a formula (model) and told, “here is a formula that you should use in this type of situation.” They were then given many opportunities to exhibit that they could use that formula in those situations.

In modeling, one of three scenarios generally occurs: **(a)** students are given some data from an actual (real-life) occurrence, **(b)** they are given a problem and told to gather the necessary data to solve the problem, or **(c)** they conduct an experiment and generate some data. The data is examined, usually with a scatter plot, and a regression procedure is used to generate a formula that fits the data. This formula/model is then used for interpolation and extrapolation. Much of this formula generation would not be possible without the use of inexpensive scientific/graphing calculators and/or computer software.

In order to use this type of modeling process, students must become much better at analyzing a graph and determining the type of function that best fits the data. They must also be able to assess whether a given model makes sense in the context of the problem situation. Understanding a problem’s natural domain and other limitations is part of such assessment.

Modeling situations create much of the other reasons for students to take algebra: formula interpretation, familiarity with mathematics notation, graphing of all elementary functions, applications of both linear and nonlinear models including piecewise-defined functions, and estimation.

**The ability to apply mathematics topics is vital.**

**Basic algebra concepts should be second nature.**

**Students need to learn to model with functions.**

**Modeling creates many of the needs for algebra.**

Another key concept that all students should acquire is a better interpretation of slope, especially with regard to the units for slope in non-traditional or in realistic problems. Many of the modeling situations provide an excellent opportunity to use slope to provide an intuitive introduction to calculus.

No doubts were expressed about the use of technology as an important tool in the teaching and learning of mathematics. Using technology will be discussed further in the Pedagogy section (see page 9).

## Geometry

Geometric topics important for technicians include the ability to use right triangles and similar triangles to model situations. Students need to be able to solve problems using the Cartesian coordinate system, especially the distance between two points. Participants were also interested in three-dimensional geometry and three-dimensional graphs.

Students were introduced to perimeter, area, and volume when they were in middle school, but these formulas and concepts need to be reinforced using practical problems that require the student to do more than substitute into a formula that is given to them. They must be able to use geometric concepts to draw pictures of problem scenarios. Geometry also provides an opportunity to show how to approximate the perimeter, area, and volume of irregular shapes and can provide another intuitive introduction to calculus.

Geometry should be integrated throughout courses with applications as appropriate. This integration will require students to recall formulas or conduct research to find the needed information.

## Trigonometry

The trigonometry needed by technicians primarily falls into three categories: right triangle trigonometry, sine graphs, and vectors. They need to be able to use these concepts to solve problems or model phenomena.

In order to use right triangle trigonometry, students have to know how to work with degrees-minutes-seconds. Because of their use in graphing (and calculus), students should encounter radians and be able to convert between radians and degrees-minutes-seconds. They will also need to use inverse trigonometric functions.

## Statistics

All students need to know some basic concepts from statistics. In particular, they need to be able to use measures of central tendency and variance to explain and/or interpret data. While they may have been introduced to correlation when they were applying regression models in algebra, these concepts will be strengthened as they are applied in statistics. Many statistical calculations will be accomplished with the

**All students should  
acquire a better  
interpretation of slope.**

**Geometry should be  
integrated throughout  
all courses.**

**All students need basic concepts from statistics.**

**Mathematics faculty should use spreadsheets as a tool.**

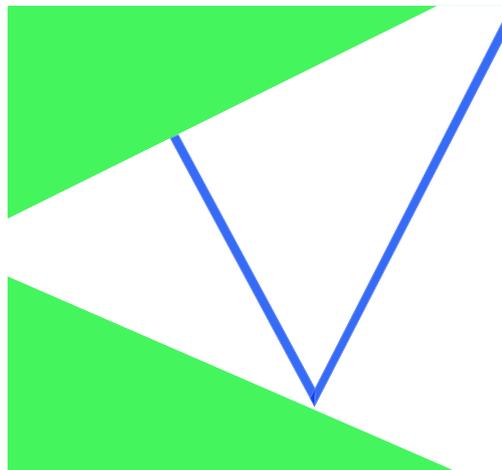
use of technology. Therefore, the emphasis must be on the ability to apply these concepts to analyze and interpret real data.

Technicians use technology to organize and display data. Since many technicians will use a spreadsheet on the job, mathematics faculty should use this technology as a tool when possible. Spreadsheets allow students to simultaneously see the data and a graph of the data. A spreadsheet gives students the opportunity to test conjectures easily by simply changing the values of the parameters in a calculation or formula. Technicians may need an introduction to hypothesis testing, perhaps with a  $t$ -test, and confidence intervals should probably be introduced. More advanced hypothesis testing might involve ANOVA or  $\chi^2$ .

Among the additional statistical topics needed by some technicians is SPC (Statistical Process Control). The use of SPC will seldom involve actual calculations because SPC will be done by computers. However, technicians will need to know how to interpret and use SPC information.

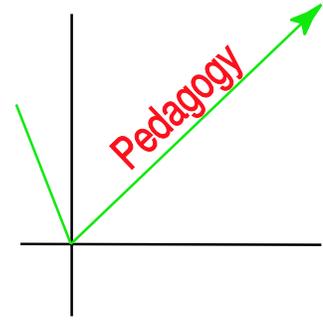
### Calculus

Most technicians will not need to use calculus. However, they will need an understanding of some of the fundamental calculus concepts. Those who do need calculus will, of course, need differentiation and integration. The conceptual introduction to both differentiation and integration can be done when students study algebra and geometry. Knowing how to differentiate and integrate functions is worthless unless students know how these operations are used and can interpret the results in the context of a real-life situation.



## Pedagogy

As the groups discussed pedagogy, they listed several different aspects of teaching: lecture/discussion, discovery or Socratic, small group, projects, teams, and various aspects of using technology. Because technology is so fundamental to technology programs, the discussion about pedagogy will include the different aspects of technology after a discussion about the types of students.



## The Learners

The discussion in one group revolved around the nature of the students who are enrolled in mathematics courses. For the most part, two-year college students are adults rather than children—and adults have different learning styles than do children.

When do children become adult learners? Adult learners are defined sociologically, not chronologically. Adult learners learn differently, and they need to be ready to learn in order to learn.

Andragogy was developed by Malcolm Knowles (1913–1997) and has been defined as the art and science of helping adults learn. Knowles' instructional model is based on assumptions about how adults learn and can also be viewed as an alternative to pedagogy, a more learner-centered approach for students of all ages.

Knowles has six assumptions<sup>4</sup> about adult learners.

1. Adults need to know why they need to learn something before undertaking to learn it.
2. Adults have a self-concept of being responsible for their own lives.
3. Adults come into an educational activity with both a greater volume and a different quality of experience from youths.
4. Adults become ready to learn those things they need to know.
5. Adults are life-centered (or task-centered or problem-centered) in their orientation to learning.
6. While adults are responsive to some extrinsic motivators... the more potent motivators are intrinsic motivators.

These assumptions about how adults learn need to be considered when one is designing the curriculum and preparing lessons.

## Technology (Other than the Internet)

Regardless of the technology that is being used, two considerations need to be kept in mind:

- Technology should be a tool, not the driving force behind the curriculum. Technology by itself is not the objective.

<sup>4</sup>Knowles M. S. (1990) *The Adult Learner: A Neglected Species* (4th edition) Houston: Gulf Publishing.

**Two-year college students are adults, not children. Adults have different learning styles than do children.**

- Professional development in the appropriate use of technology as a tool to teaching and as a tool for learning should be made available to all faculty including adjunct faculty. (Professional development will be discussed in the Currency section starting on page 17.)

**Discussion was not about whether technology should be used but rather how it could be used.**

The use of technology in a mathematics class usually involves either graphing calculators or computers. Discussion did not revolve around *whether* technology *should* be used but rather *how* it *could* be used.

Graphing calculators began appearing in mathematics classrooms in the late 1980s, but it was not until the introduction of the TI-81 calculator in 1990 that graphing calculators began to be widely integrated into mathematics education.

Graphing calculators do more than just graph functions. Most allow tables to be generated either by the user entering specific data points or by the user entering a function which the calculator evaluates at a specified set of values.

A user-entered set of data points can be graphed on a calculator, and various functions can be generated using regression features built into the calculator. The types of functions include 2nd, 3rd, and 4th degree polynomials, exponential, logarithmic, sinusoidal, and, with some effort by the user, piecewise.

Spreadsheets are alternatives to graphing calculators. An obvious reason to use spreadsheets is the fact that they are the technology of choice for business and industry. An obvious drawback is that personal computers are not always available in classrooms. Other advantages of the spreadsheet over the calculator include its ability to simultaneously display data and graphics and the ability of the spreadsheets to be interactive with the users. A spreadsheet can be more easily integrated into a written (word processed) document.

**Spreadsheets are the technology of choice for business and industry.**

Computer algebra systems (CAS), such as Derive™, Maple®, MathCad®, and Mathematica®, have many of the same advantages as spreadsheets. However, MathCad® and Mathematica® probably are better at integrating data, graphs, and mathematical expressions with text.

All of these types of technology, graphing calculator, spreadsheet, and CAS, allow students to examine, organize, and analyze real data. Because they are pursuing careers in areas that require technology, the ability to use technology to examine, organize, and analyze real data should be a natural extension of the student's technical program.

**Students have to organize their thinking and select from multiple solution strategies.**

The major advantages of using these technologies is that students can use realistic data, they have to organize their thinking, and they often have to select from multiple solution strategies. Justification of the method selected affords excellent learning opportunities.

Use of multiple technologies gives students the chance to understand how to use each technology and its limitations. Technology also provides situations for students to emphasize the need to estimate solutions

and check their work.

## The Internet

The Internet can be an excellent source of realistic data. It can also be a source of misinformation. On occasion, examination of different web sites will result in different data for the same situation.

Many research activities can be facilitated by using the Internet. Java applets can be used as teaching or computation tools. Teaching students to use the Internet will probably do more to promote lifelong learning—one of the major goals of higher education.

The Internet can help teach students how to use reference materials (including the textbook). It can also use the problem-solving process as a tool and set up situations where students analyze what is relevant to a particular problem and determine what simplifying assumptions to make in order to solve the problem.

**The Internet facilitates many research activities.**

## Teaching-Learning Methods

The lecture-discussion method has been around for centuries, and despite all the calls to replace it with other methods, it will undoubtedly continue to be an appropriate way to provide information in some circumstances. However, this group calls for lectures to be supplemented with a variety of student-centered methods, such as computer simulations, web-assisted activities, collaborative learning activities, and instructional television. The inclusion of technology in the lecture provides opportunities to enliven the teaching and to get students more actively involved in the learning process.

**Lectures should be supplemented with a variety of student-centered methods.**

Technology also allows a lecture to be interspersed with multiple choice questions which students anonymously answer. The responses provide instructors with instantaneous feedback as to whether students have understood a certain idea. Responses can also be used to measure student attitudes.

Instructors should also use collaborative techniques as alternatives to lecture. These methods may do a better job of providing students with situations similar to ones they might encounter at work. While some uses of technology mean that students can work alone, others require that they have to collaborate and work in teams.

**Instructors should use collaborative techniques.**

Collaborative learning opportunities include working in teams. One advantage of collaborative learning and small group work is that they require students to communicate effectively both orally and in writing, not only with each other but with the instructor.

## Outside Contributors

Recent graduates, industry retirees, and other practitioners bring experiences that students can find valuable.

Collaboration with other departments and staff help faculty develop interdisciplinary skills that are expected of the students (oral, written, and other communications). Working with other faculty members helps mathematics instructors incorporate familiar content from other disciplines.

## Pedagogy Affected by Material

### Activities

**Activities should be a normal occurrence in math class.**

The use of activities to engage students in the learning process should be a normal occurrence in the mathematics classroom. Activities may require students to do a short experiment to collect data or show a phenomenon. An activity may be a problem posed to groups of students or it may be some type of assessment of students or instruction. An activity may involve technology (animations or graphics). Activities may require the students to discuss, plan, or write and should provide a chance to engage students with various learning styles.

### Projects

**Projects can engage faculty from other disciplines.**

Projects require a student or group of students to design, plan, organize, research, calculate, model, and/or present. They differ from activities in that they require more than a class period to complete and often require students to meet or communicate outside of the classroom. Projects provide opportunities to engage faculty from other disciplines. The context of a project may come from one of the technologies. Technology faculty may make a guest appearance to set up the project. English faculty may assist students in the written or oral part of the project.

### Scenarios (Problem-Based Learning)

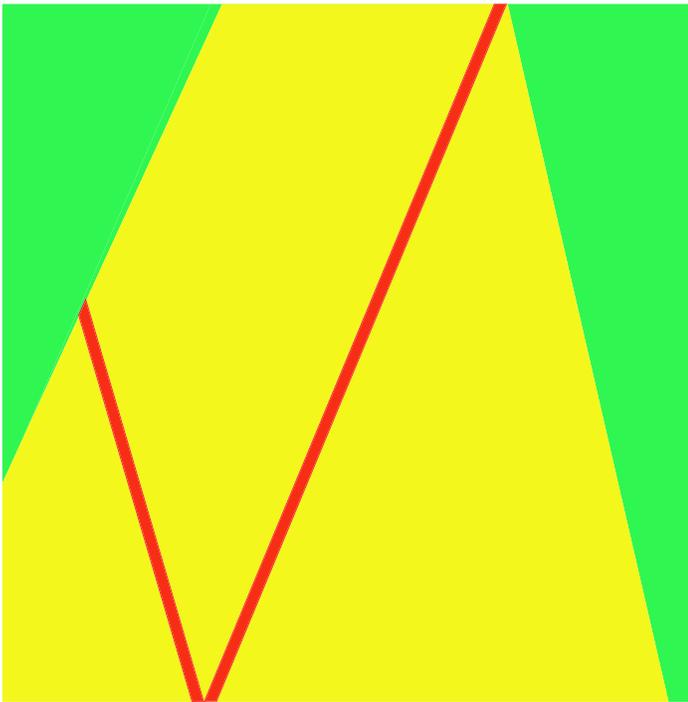
Scenarios or case studies provide another way to engage students in meaningful activities. The problems are often vaguely defined, and there may be several acceptable solutions. Scenarios or case studies are more often used within an integrated curriculum (or within a learning community). The problem may be very technical in nature but require the student to use skills in mathematics, science, and English.

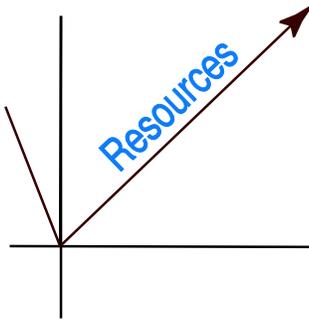
## Pedagogy Affected by Industry/ Workplace Environment

**All students must learn to be responsible.**

All students must learn to be responsible. They must learn to attend class (on time), be involved with the discussion, be aware of all requirements, and meet deadlines. While mathematics instructors cannot achieve these goals alone, they must contribute to the end result. Mathematics faculty must set high standards for students and require

work to meet those standards without excuses. Mathematics instructors must demonstrate these attributes by being prepared, using best practices, and meeting deadlines.





## Resources

Resources are the tools and other material that support mathematics instruction. There are three major categories: physical resources, human resources, and fiscal resources.

### Physical Resources

The physical resources have several subcategories such as the classroom environment, equipment needs, classroom management systems, and textbooks.

#### Classroom Environment and Equipment

Most students in the technical mathematics classroom today use graphing calculators. In the near future we would expect that all students in these classes would have a laptop computer or a personal digital assistant (PDA). *All* classrooms should have network connectivity with multimedia and projection capabilities built in.

Students and faculty should be able to exchange files using wireless connections and should be able to integrate the use of computer software, calculators, PDAs, and the world wide web.

Mathematics faculty must encourage the use of technology and foster computer literacy. The web allows students to communicate with each other and their instructors as well as allowing faculty to communicate with each other.

Equipment needs might include smart boards, and smart classrooms—projection unit, DVD, computer connections, document camera, digital camera—interactive classrooms with video conferencing capabilities to off-campus students and to industry, climate control and energy sensitive lights and equipment, “holographic” instructors, and electronic linking to labs.

The furniture in the room must be different from the desk-chairs that have been *de rigueur* for over 50 years. At present, students cannot have an open textbook, laptop computer, and graphing calculator on the desk at the same time. In fact, in some rooms, it is difficult to simultaneously use a notebook and a graphing calculator.

Rooms need to be equipped with furniture that fosters collaboration and is large enough for students to conveniently use both a laptop computer and the text.

#### Classroom Management Systems

Management systems, such as WebCT and Blackboard, enable the quick dissemination of syllabi, assignments, and updates. These web-based management systems provide instructors with new ways of promoting daily homework using quick on-line quizzes and better ways of

**Mathematics faculty must encourage the use of technology.**

**Rooms should have furniture that is large enough to use both a laptop computer and the text.**

helping students review and learn material (animations, access to other texts, and access to previous exams).

Many of these systems also have chat rooms and whiteboard capabilities. The chat room allows students to discuss, either with peers or the instructor, areas where they are having problems. However, it is often difficult to type mathematics in these systems.

Students need to be comfortable with technology that uses both symbolic mathematics and arithmetic. It may be that students don't need a specific software package, but they do need the skills and the experience with these types of technologies that they can readily learn and adapt when confronted with a specific software package.

**Students need to be comfortable with technology that uses both symbolic mathematics and arithmetic.**

## Textbooks

Participants would like to see a reform movement in mathematics books. Textbooks should include writing assignments, projects, technology-based activities, a sufficient amount of skill-and-drill, useful web materials, and information that is relevant to the technologies represented in their mathematics courses.

To get texts to change, faculty must tell publisher's representatives what they want and what they need. The need for textbook reform must be said to representatives who visit faculty and when faculty visit a publisher's booth at a conference.

Good, sound, basic textbooks are needed that form the basis for web and other ancillary materials. When a textbook offers the new direction, the ancillary materials will follow.

Books need to include problems that more realistically reflect real world applications. For example, some problems need to provide too much information and other problems should omit some information. Students need to use the appropriate technology to model actual situations.

**Publishers must be told that textbook reform is needed.**

## Human Resources

In addition to full-time faculty, the human resources section has two primary subcategories: learning communities and adjuncts.

### Learning Communities

Learning communities<sup>5</sup> may be thought of in two ways:

- Learning communities can be topic experts, industry personnel, local professional organizations, and the student's classmates who can serve as instructional aides.

<sup>5</sup>The information technology area refers to a learning community as a "community of interest."

**Mathematics departments should help form learning communities.**

- Learning communities may also be a group of instructors who plan, coordinate, and offer a set of courses with a common theme or shared projects.

A learning community can provide a supportive environment for students. Mathematics departments should help form learning communities either entirely within mathematics or in conjunction with one or more technical areas.

The formation of various learning communities, either by the students themselves or by faculty assistance, can help many students. Since, in some cases, it may be especially difficult for commuting students or part-time employed students to form such groups, on-line bulletin board or chat rooms can be used to enhance student communication.

### Adjuncts

**Adjuncts and full-time faculty must remain current.**

With “reformed” curricula and classrooms, in-service training (possibly paid) for adjuncts is essential. Adjuncts need offices and access to computers for e-mail and instruction. They also need class training, technical support, orientation, recognition, and monetary support for professional development activities.

Both adjuncts and full-time faculty must remain current. While these concerns were discussed by some groups in this section, the recommendations will be deferred to the next Section, “Keeping Current.”

### Fiscal Resources

**Faculty need to be compensated as professionals.**

Faculty, including adjuncts, need to be compensated as professionals. This issue is more critical in some states than others. The salary of two-year college mathematics faculty should be high enough to attract and retain the type of people who will provide positive role models for our future citizens and workforce.

The support for faculty must also be shown in the teaching load required of faculty members. Faculty who teach 15–20 hours or more find it difficult to remain current or find the time to do research and to try new ideas.



## Keeping Current

Mathematics faculty must remain current if they are to provide an up-to-date curriculum, hone their pedagogical skills, and use the latest technology and other resources. These are problems for both adjuncts and full-time faculty. The following were among the specific suggestions for professional development.

- The institution should have an institutional coordinator of and an institutional commitment to professional development.
- Both adjuncts and full-time faculty should have opportunities for professional development.
- Instructor evaluation should include one’s professional development.
- Technical support people should have opportunities for professional development.
- Faculty should receive support for release time to participate in professional development.

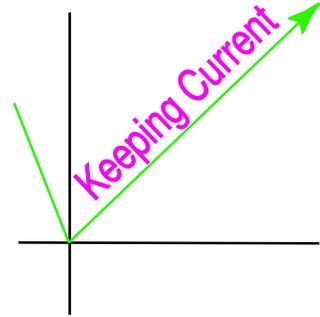
Two of the best ways to keep current are to read the professional literature and participate in professional meetings. Not only should instructors read mathematics journals such as *The AMATYC Review*, *The College Mathematics Journal*, NCTM’s *Mathematics Teacher*, and *The Journal of Online Mathematics and its Applications* but they should also read non-math journals such as *Prism* and the *Journal of Engineering Technology*.

Two-year college mathematics faculty should attend AMATYC national conferences and meetings of affiliate organizations. Conferences provide an opportunity to share ideas and discuss challenges with colleagues. The conferences also provide a venue where faculty can learn about innovative programs and pedagogy. Mathematics faculty, especially technical mathematics faculty, should participate in meetings of technical associations like ASEE (the American Society for Engineering Education) and IEEE (the Institute of Electrical and Electronics Engineers).

Since not all faculty are able to attend national conferences, faculty who do should share findings and experiences from professional meetings with others in the department by giving presentations during department meetings, with internal written reports, and/or by writing articles in newsletters.

Many professional organizations offer workshops that help faculty keep current. One example is AMATYC’s “Traveling Workshops.” Some of these can be offered on, or near, the local campus and are usually less than a day long. Others, such as AMATYC’s summer institutes, can last a week or more and require traveling a great distance.

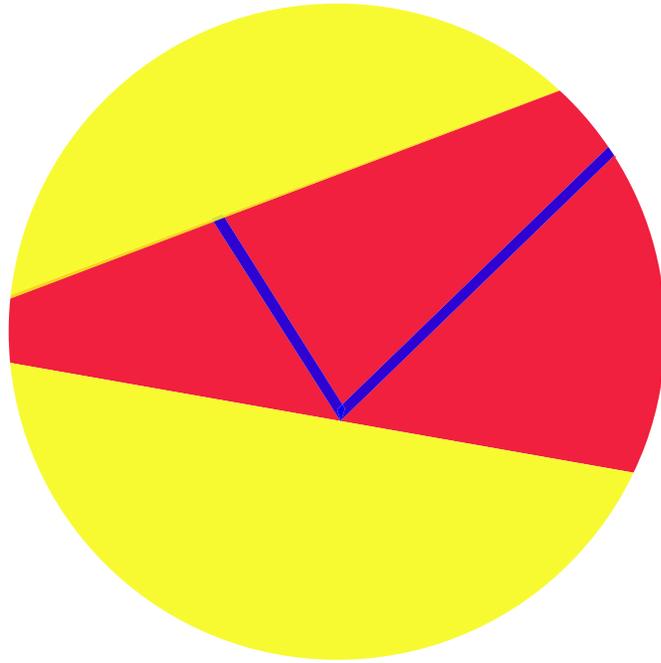
Participants felt that technical mathematics faculty should gain some experience in industry, which could involve tours of industry,



**Read the professional literature and participate in professional meetings**

**Faculty should share findings and experiences from professional meetings.**

talking to graduates, and job shadowing. As an alternative, industry representatives could speak at faculty and advisory meetings. 



## Maintaining a Successful Program

In order to maintain a successful program, departments need to identify methods of attracting students and to generate graduates who are able to find employment in their field of study.

One group felt that in order to have a successful program we should eliminate the perception of “Mathematics = Barrier.” This perception will be mentioned first. The other major categories of recommendations are partnerships, articulation, and community involvement.

### “Mathematics = Barrier” Perception

Many people perceive mathematics as a barrier that needs to be hurdled or maybe just climbed over in order to gain entrance to their selected careers. Perhaps the biggest key to maintaining a successful program is the ability to reduce this perception.

To help show that “Mathematics  $\neq$  Barrier,” the relevance, utility and criticality of mathematics to a career must be demonstrated not only to students but to their parents, advisors, faculty in other disciplines, and other stakeholders such as boards of trustees.

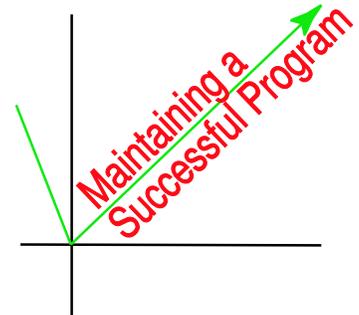
Recognizing and addressing issues of student diversity (diversity includes race, gender, age, economic conditions, ADA, ESL and other access issues) are other ways to reduce the “Mathematics = Barrier” perception. Because so many students come to two-year colleges with poor mathematics skills, we need to develop ways to remediate that are **more in-depth and applications-based**. Increased diversity of faculty within technical mathematics and technical programs will also help eliminate the “Mathematics = Barrier” perception.

Additional suggestions for individual mathematics faculty and leadership include: getting involved in, and attending, division meetings of technical programs; volunteering to be on advisory boards; establishing partnerships with business, high schools, industry, civic groups, and trade unions; giving presentations about technical mathematics with applications; teaching selected topics in high schools; and holding or hosting monthly mathematics seminars for all faculty.

Given the large number of possible activities and actions, it was noted that no one person could do or implement each and every recommendation. A faculty member should start by doing one or two things differently, or choose to change something, not everything. Change is a gradual process, not a sudden revolution. Change can be either conscious or unconscious. We think it should be conscious and directed, even if a little at a time.

### Partnerships

Three types of partnerships were suggested: with technology faculty, with business and industry, and with high schools.



**The relevance, utility and criticality of mathematics to a career must be demonstrated.**

**Recognizing and addressing issues of student diversity will reduce the “Mathematics = Barrier” perception.**

**Start by doing one or two things differently.**

**Mathematics programs should establish partnerships with technology faculty.**

**Math faculty should regularly meet with faculty in technical areas.**

**Mathematics faculty should participate in local professional organizations.**

**Invite high school personnel to activities demonstrating technical programs.**

### **Partnerships with Technology Faculty**

Mathematics programs should establish partnerships with technology faculty by including technology faculty on mathematics hiring committees. Technology areas should reciprocate by including mathematics faculty on technology hiring committees.

The mathematics faculty should solicit applications from the technology faculty. They should visit and observe technology classes to see what mathematics is used and how it is used. Individual faculty members should invite technology faculty to explain and/or demonstrate applications that use certain mathematical topics. Similarly, technology faculty could invite mathematicians to occasionally teach certain mathematics concepts.

Mathematics faculty should regularly meet with faculty in all technical areas to discuss content, to learn about new technology and new uses of old technology, and to discuss any modifications that need to be made in the curriculum.

### **Partnerships with Business and Industry**

Partnerships should also be established with business and industry. Mathematics departments should establish mathematics advisory committees that include both technology faculty and business and industry representatives. These advisory committees would be an excellent means for keeping programs up-to-date, for providing useful information for planning and assessment, and for recruiting guest speakers and adjunct faculty.

Business and industry partnerships would also provide opportunities for offering specialized courses and programs for workforce training. Mathematics faculty should participate in local professional organizations, and industry representatives should be invited to share with the mathematics department ways in which they use math.

### **Partnerships with High Schools**

College mathematics faculty should participate in Tech Prep partnerships and career fairs. They can also provide in-service professional development for high school faculty.

High school math teachers often are not fully aware of the mathematics expectations of collegiate faculty and the extent that technology is used in college mathematics classes. College faculty often complain about the poor preparation of entering students. Improving communication between the area high schools and the college mathematics programs can help reduce these misunderstandings.

College mathematics departments should invite high school counselors, administrators, and teachers to hands-on activities demonstrating technical programs. College faculty members could take students

in the technical programs into high schools for talks, demonstrations, and “college” career days.

### Articulation

A big problem encountered by schools where a large percentage of students transfer to four-year programs is the fact that two-year courses do not transfer to four-year colleges and universities. It is interesting that many colleges have lower-level mathematics courses that do transfer, but that technical mathematics courses which often include the same content as precalculus courses, but with an applied viewpoint, do not transfer. Many two-year colleges have changed their technical mathematics courses to one in college algebra and trigonometry, often a mixed blessing. While college algebra and trigonometry courses will transfer, they often do not contain the applications that make the mathematics meaningful.

We need to explore ways of promoting transferability of mathematics courses for students in emerging technologies to baccalaureate programs. More dialogue between two- and four-year colleges is necessary on this issue. Students choosing technical curricula need workplace relevance in their mathematics courses and should not be unduly penalized for their choice if they opt to continue their education.

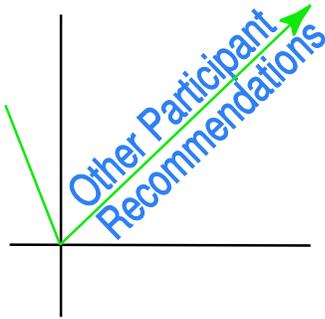
**We need to promote the transferability of mathematics courses to baccalaureate programs.**

### Community Involvement

In addition to the above suggestions, mathematics departments should establish and/or strengthen connections with civic organizations. Not only should faculty speak at meetings of these organizations, but the department should also invite members of organizations such as the Lions and Rotary Clubs to serve on advisory boards and provide guest speakers.

The college should encourage civic organizations to establish student scholarships at the college and encourage the organizations to participate in the evaluation and judging of general education presentations and papers.





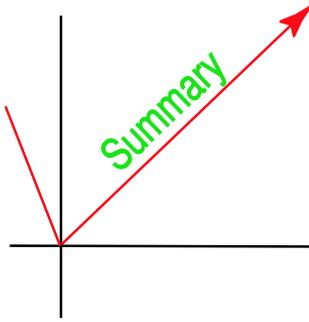
## Other Participant Recommendations

The following are items that either are not contained in the matrices or were felt to be worthy of special emphasis.

- Help mathematics departments in the nation's community colleges begin to examine how, as a department, faculty can work together to improve the teaching and learning of mathematics. Identify departments that have successfully implemented and institutionalized innovation in their mathematics programs. Analyze the group dynamics and team building skills that lead to the transformation of mathematics teaching throughout an entire department, and share this knowledge with other mathematics departments.
- Establish a national clearinghouse for (a) sharing information about reform of technical mathematics and (b) sharing authentic application problems. The clearinghouse should have a dedicated staff, probably with initial government funding, but ideally to be eventually supported on a permanent basis through industry funding. The clearinghouse should contain
  - Projects
  - Case studies
  - Web sites
  - Assessments
  - Problem-based learning activities
  - Software
- Establish Internet-based capability for faculty to share applied problems they develop.
- Establish a Technical Mathematics journal emphasizing authentic industrial applications. The journal should include but not be restricted to applications for courses below calculus.
- Explore ways of promoting transferability of technical mathematics courses to baccalaureate curricula. Students choosing technical curricula need workplace relevance in their mathematics courses, but they should not be unduly penalized for their choice if they opt to continue their education (as many eventually will).
- Collect assessment data on outcomes of a reformed technical mathematics course sequence, including affective as well as cognitive outcomes. Subsequent performance in mathematics-intensive technical courses may be equally as important as performance in higher level math courses. Enlist the support of technical faculty to help convert resistant mathematics faculty.
- Adopt the “reform” recommendations proposed by this conference in higher level mathematics courses taken by technical students.

- Provide ways to continue discussions similar to those of this conference and the CRAFTY workshops.
- Put time and money into tracking what reform progress is happening, following students, and assessing the effect. Should we try to make connections to ABET? Should we have a joint effort with ABET?
- Increase our visibility. Connections to industry organizations will be a next step. The Society for Human Resource Management is a suggestion. Look at skill standards generated by industry.
- Use a system that includes several different types of evaluation. Good assessment involves a variety of techniques.
- Provide professional development to K–12 teachers to help them more realistically provide meaningful examples from the technologies. The professional development should also provide examples and experience in using appropriate technology for teaching and learning.
- Increase our political power, particularly on the state level, which is where curriculum and course content are dictated.





## Summary

In many ways, the following statements apply to the entire mathematics curriculum in the first two years of college, not to just the mathematics courses for students in emerging technologies.

- Critical thinking, problem solving, and communicating mathematically transcend all mathematics.

The general ideas of critical thinking, problem solving, and communicating mathematically can and should be taught in all levels of mathematics. Expected student outcomes should be based less on specific content skills and more on problem solving, critical thinking, and communicating mathematically.

- Traditional content is NOT appropriate today.

All students need statistics, and many will not need the heavy dose of algebra that is traditionally required. Additional topics in discrete mathematics and modeling should be added to the curriculum, not necessarily as separate courses, but through integration with existing material. Content should be addressed in ways that demonstrate connections between mathematics and other areas, as well as among mathematics topics.

- Memorizing isn't all there is to learning!

Students must acquire a deeper understanding of mathematical topics. They must apply the topics to non-traditional problems and be able to apply the appropriate tools to unfamiliar situations, not just those found at the end of a chapter. Having "covered" a section in a course isn't a measure of success—it's what the student learned and thus can apply that is important.

- Applications should have local depth and global breadth.

Students must be able to transfer the mathematics knowledge or skills to applications within their disciplines. Focusing on local businesses gives immediate relevancy to applications. Yet, examples must be transferable outside the local community.

- Faculty must use technology as a tool for teaching and, at the same time, develop the ability of students to use that technology to solve problems.

Students will use technology in the workplace. The classroom should model the workplace if we are to equip students to succeed in a variety of settings. Instructors must use technology to enable students with different learning styles to grow mathematically. Technology enables us to solve more realistic problems that aren't already designed and trivial.

- The classroom environment must use all the resources possible to facilitate learning.

The classroom must be designed and equipped with appropriate furniture and technology so that a variety of formats can be used to facilitate learning. Students and instructors will use many tools in class, so the space must enable, not hinder, the learning process. The environment must also be conducive to collaboration, both verbally and electronically. Students should be able to share their ideas and findings using a variety of tools.

- Teaching math is not just teaching math.

Mathematics faculty must help provide students with a variety of habits (soft skills) that will enable them to succeed in the workplace as well as be good citizens and life-long learners. The skills that employers want from their employees rarely include specific content. They want instructors to strengthen the students' ability to think, to communicate, and to be responsible. Mathematics classes must be a part of equipping the student with employability skills.

- Teaching can't be done in isolation.

Mathematics faculty must keep current with the changes and needs of students who are majoring in other disciplines. Schools and departments must find ways to motivate mathematics faculty to communicate regularly with faculty in other departments and with practitioners in industry.

Faculty must be involved in professional activities that keep them current and provide them with new ideas and with information about best practices. Schools and departments need to examine the current structure that promotes the *status quo* and isolation. Education institutions must find ways to promote innovation, sharing, and personal growth.

- Decisions should not be made in isolation

Educators who attempt to provide the appropriate experiences for students who will soon enter the workplace must be aware of the skills required in the workplace.

Mathematics faculty must find ways to learn about the employability skills their students will need to be successful employees or employers. By performing workplace research, better decisions will be made regarding the appropriate content, technology, and pedagogy for tomorrow's classrooms. The old answers to the question of "Why do we need to know this?" ("Because it is on the next test." or "Because you'll need it in the next course.") are not sufficient. We need to be able to provide realistic examples that motivate content.

- Institutions must set the example

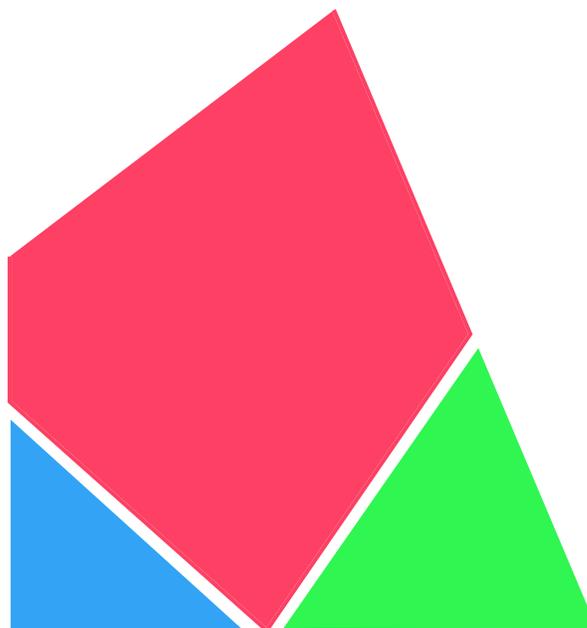
The technology students use in the classroom must help equip them to deal with the highly technical workplace of the future.

Schools must find ways to fund up-to-date equipment and software as well as ways to ensure faculty are using those resources appropriately.

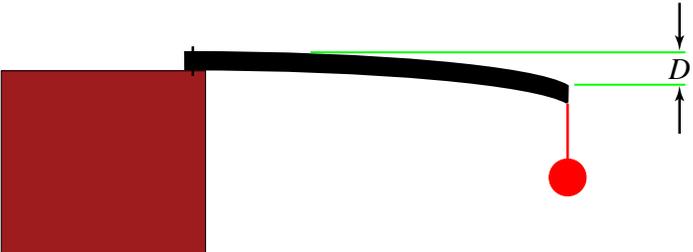
Students should be able to communicate with each other and with the instructor in a wireless environment that makes formative assessment and instructive communication easy. The infrastructure should promote methodology that utilizes the capabilities of the personal computer, especially as it relates to ways to aid explanations visually through pictures, videos, or animations.

- All mathematics faculty are equal.

Adjunct faculty should have the same benefits as full-time faculty. This especially applies to opportunities and monetary support for professional development.



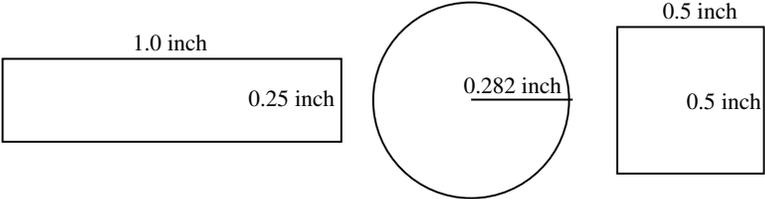
# Bloom's Taxonomy

Competence	Skills Demonstrated
Knowledge	<ul style="list-style-type: none"> <li>• Observation and recall of information</li> <li>• Knowledge of dates, events, places</li> <li>• Knowledge of major ideas</li> <li>• Mastery of subject matter</li> <li>• Question Cues: list, define, tell, describe, identify, show, label, collect, examine, tabulate, quote, name, who, when, where, etc.</li> </ul> <p><b>Mathematics example:</b> Given <math>D(m) = 0.00002m^3 - 0.0002m^2 + 0.0003m</math>, find <math>D(50)</math>.</p>
Comprehension	<ul style="list-style-type: none"> <li>• Understand information</li> <li>• Grasp meaning</li> <li>• Translate knowledge into new context</li> <li>• Interpret facts, compare, contrast</li> <li>• Order, group, infer causes</li> <li>• Predict consequences</li> <li>• Question Cues: summarize, describe, interpret, contrast, predict, associate, distinguish, estimate, differentiate, discuss, extend</li> </ul> <p><b>Mathematics example:</b> A cantilever beam is supported on one end, and an object is placed on the other end, as shown in Figure 1. The distance the beam is bent from the horizontal position is called the deflection. The formula <math>D(m) = 0.00002m^3 - 0.0002m^2 + 0.0003m</math> uses the weight of the object to determine the deflection. Find the deflection for a weight of 2 pounds.</p> <div style="text-align: center;">  </div> <p style="text-align: center;">Figure 1</p>

*Continued on next page*

Competence	Skills Demonstrated
Application	<ul style="list-style-type: none"> <li>• Use information</li> <li>• Use methods, concepts, theories in new situations</li> <li>• Solve problems using required skills or knowledge</li> <li>• Questions Cues: apply, demonstrate, calculate, complete, illustrate, show, solve, examine, modify, relate, change, classify, experiment, discover</li> </ul> <p><b>Mathematics example:</b> Attach different weights to the end of the cantilever beam in Figure 1. Determine quadratic, cubic, and quartic formulas for the amount of deflection in the beam in Figure 1 as a function of the weight on the end.</p>
Analysis	<ul style="list-style-type: none"> <li>• Recognition of patterns</li> <li>• Organization of parts</li> <li>• Recognition of hidden meanings</li> <li>• Identification of components</li> <li>• Question Cues: analyze, separate, order, explain, connect, classify, arrange, divide, compare, select, explain, infer</li> </ul> <p><b>Mathematics example:</b> As shown in Figure 2, a simply supported beam is placed across an open space and is not supported at either end. Explain how you would design an experiment to find the deflection of the beam as a function of the weight placed on the beam.</p> <div style="text-align: center;">  <p>Figure 2</p> </div>
Synthesis	<ul style="list-style-type: none"> <li>• Use old ideas to create new ones</li> <li>• Generalize from given facts</li> <li>• Relate knowledge from several areas</li> <li>• Predict, draw conclusions</li> <li>• Question Cues: combine, integrate, modify, rearrange, substitute, plan, create, design, invent, what if?, compose, formulate, prepare, generalize, rewrite</li> </ul> <p><b>Mathematics example:</b> A 24-inch long beam is supported on one end (a simply supported beam). An object placed on the end of the beam will cause the beam to bend (deflection). The amount of deflection is dependent on several factors. You will be provided plastic “beams” with the three different cross-section shapes shown in Figure 3—all with a cross-sectional area of 0.25 square inches.</p>

*Continued on next page*

Competence	Skills Demonstrated
Synthesis ( <i>cont.</i> )	<div style="text-align: center;">  <p>Figure 3</p> </div> <p>Each group of three students will determine a model for the deflection of each beam as a function of the mass on the end (using masses between 50 and 100 grams). Write a report on the process used to determine the model, describe the model and the extent that the model is reasonable. Use the model to predict the deflection with a 200-gram mass. AFTER making the prediction, find the deflection and calculate the percent error in your estimate. Which design of the beam is “best”? (Discuss)</p>
Evaluation	<ul style="list-style-type: none"> <li>• Compare and discriminate between ideas</li> <li>• Assess value of theories, presentations</li> <li>• Make choices based on reasoned argument</li> <li>• Verify value of evidence</li> <li>• Recognize subjectivity</li> <li>• Question Cues: assess, decide, rank, grade, test, measure, recommend, convince, select, judge, explain, discriminate, support, conclude, compare, summarize</li> </ul> <p><b>Mathematics example:</b> Compare the accuracy of the quadratic, cubic, and quartic regression equations you developed in the Applications Example. Explain which formula is the most accurate.</p>



# National Conference Participants

The following people attended the May 12–15, 2002 national conference to establish a vision for the mathematical needs of students in emerging technologies.

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Edison State Community College, Piqua,  
Ohio
- Martha Haehl**, Administrative Intern, Blue  
River Community College, Blue Springs,  
MO
- Chuckie Hairston**, Mathematics Instructor,  
Wake Technical Community College,  
Raleigh, North Carolina
- Eric Hiob**, Mathematics Instructor, British  
Columbia Institute of Technology,  
Burnaby, British Columbia
- Patricia Hirschy**, Associate Professor of  
Mathematics, Asnuntuck Community  
College, Enfield, Connecticut
- Jan Hoeweler**, Mathematics Instructor,  
Cincinnati State Tech & C.C., Cincinnati,  
Ohio
- Amy Hoffman**, Mathematics Instructor,  
Community College of Baltimore County,  
Essex Campus, Baltimore, Maryland
- Linda Hollstegge**, Instructor, Info &  
Engineering Tech, Cincinnati State  
College, Cincinnati, Ohio
- Wayne Horn**, Director Computer Science  
Programs, Pensicola Junior College,  
Pensicola, Florida
- Mary Ann Hovis**, Math Chair, James A.  
Rhodes State College, Lima, Ohio
- Robert Hovis**, Professor and Program  
Director (Computer Science), Ohio  
Northern University, Ada, Ohio
- Don Hutchison**, Mathematics Chair,  
Clackamas Community College, Oregon  
City, Oregon
- James Hyder**, F11X Training Developer  
(Thin Films), Intel Corporation,  
Hillsboro, Oregon
- Gerald Janey**, Chairman of Engineering  
Tech, Massasoit Community College,  
Brockton, Massachusetts
- Elaine Johnson**, Bio-Link Director ATE  
Center, City College of San Francisco,  
San Francisco, California
- Wendie Johnston**, Director, Net  
Biotechnology Center, Pasadena City  
College, Pasadena, California
- Vern Kays**, Assistant Professor Mathematics,  
Richland Community College, Decatur,  
Illinois
- Robert L. Kimball**, Department Chair of  
Math/Physics, Wake Technical  
Community College, Raleigh, North  
Carolina
- Susan La Fosse**, Assistant Professor in  
Mathematics, Dutchess Community  
College, Poughkeepsie, New York
- Margaret Ann Leonard**, Assistant  
Professor, Mathematics, Hudson Valley  
Community College, Troy, New York
- Philip Lootens**, Dean for Sciences,  
Engineering and Communication Arts,  
Edison State Community College, Piqua,  
Ohio
- Lynn Mack**, Director of Instructional  
Development, Piedmont Technical  
College, Greenwood, South Carolina
- Philip Mahler**, President AMATYC,  
Mathematics professor, Middlesex  
Community College, Bedford,  
Massachusetts
- Robert Malena**, Professor of Mathematics,  
Community College of Allegheny County,  
West Mifflin, Pennsylvania
- Cyrus McCarter**, Instructor of Mathematics  
and Physics, Wake Technical Community  
College, Raleigh, North Carolina

- Lyle McCurdy**, Professor Electrical & Computer Engineering Technology, Dept. of Engineering Technology, California State Polytechnic University, Pomona, California
- Carol McVey**, Technical Mathematics Instructor, Florence-Darlington Technical College, Florence, South Carolina
- Michael Miller**, Mathematics Instructor, Wake Technical Community College, Raleigh, North Carolina
- Jeanette Mowery**, Biotechnology Instructor, Madison Area Technical College, Madison, Wisconsin
- Jennifer Nichols**, Assistant Professor, Mathematics, Hudson Valley Community College, Troy, New York
- Rodney Null**, Associate Professor of Mathematics, James A. Rhodes State College, Lima, Ohio
- Carolyn Pabian**, Instructor/Mathematics, Delaware Technical and Community College, Wilmington, Delaware
- Edward Pabian**, Coordinator, Industrial Training Division, Delaware Technical and Community College, Newark, Delaware
- Arnold Packer**, Senior Fellow Institute for Policy Studies, Johns Hopkins University, Baltimore, Maryland
- John Palmer**, Professor of Manufacturing Engineering/Electronics Technology Program, Industrial/Electronics, Central Arizona College, Signal Peak Campus, Coolidge, Arizona
- Jesse Parete**, Chair, Department of Mathematics, Edison State Community College, Piqua, Ohio
- Mary Parker**, Professor of Mathematics, Austin Community College, Austin, Texas
- James Payne**, Supervisor Tech Support & Mgmt Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee
- Kathleen Peak**, Mathematics Instructor, Rochester Community & Technical College, Rochester, Minnesota
- John C. Peterson**, Professor of Mathematics, Chattanooga State Technical Community College, Chattanooga, Tennessee
- Ellena Reda**, Mathematics Instructor, Dutchess Community College, Poughkeepsie, New York
- John Reed**, President, The Learning Business, Baton Rouge, Louisiana
- Stephen Rodi**, Professor of Mathematics, Austin Community College, Austin, Texas
- Branislav Rosul**, Professor of Mechatronics, College of DuPage, Glen Ellyn, Illinois
- Nancy Sattler**, Associate Dean for Curriculum, Terra Community College, Fremont, Ohio
- Albert Schwabenbauer**, Aerospace Manufacturing Consultant, Wallingford, Connecticut
- Dan Schwartz**, Manager, Supply & Transportation Systems Development Group within IT, Marathon Ashland Petroleum, Findlay, Ohio.
- Lisa Seidman**, Biotechnology Instructor, Madison Area Technical College, Madison, Wisconsin
- Witold Sieradzan**, Dean, Computer Information Systems, Wake Technical Community College, Raleigh, North Carolina

**Gary Simundza**, Professor of Mathematics,  
Wentworth Institute of Technology,  
Brookline, Massachusetts

**Donald Small**, Professor of Mathematics,  
United States Military Academy, West  
Point, New York

**Deanne M. Sodergren**, Interim Department  
Chair, Mathematics Department, Hudson  
Valley Community College, Troy, New  
York

**Joseph Stearns, Jr.**, Mathematics  
Instructor, ATE Faculty, Tri-County  
Technical College, Pendleton, South  
Carolina

**Ronald Talley**, EET Department Head,  
Tri-County Technical College, Pendleton,  
South Carolina

**Robert Templin**, Senior Fellow, Morino  
Institute, Reston, Virginia

**Gwen Turbeville**, Instructor of Mathematics,  
J. Sargent Reynolds Community College,  
Richmond, Virginia

**Emin Turker**, Dean of Engineering  
Technologies, SUNew York Canton,  
Canton, New York

**George Vaughan**, Professor of Higher  
Education, North Carolina State  
University, Raleigh, North Carolina

**Jesse Williford**, Instructor of Mathematics  
and Physics, Wake Technical Community  
College, Raleigh, North Carolina

**Darlene Winnington**, Mathematics  
Instructor, Delaware Technical &  
Community College, Newark, Delaware

**Jim Wood**, Division Chair, Ind'l & Eng Tech,  
Tri-County Technical College, Pendleton,  
South Carolina

**William Woodruff**, Department Head  
Biotechnology, Alamance Community  
College, Graham, North Carolina

**Deborah Woods**, Associate Professor of  
Mathematics, University of Cincinnati,  
Raymond Walters College, Cincinnati,  
Ohio

**Howard Woods**, Adjunct Instructor in  
Information Technology, College of  
Applied Science, University of Cincinnati,  
Cincinnati, Ohio

**Michelle Younker**, Associate Professor and  
Lead Teacher of Mathematics, Terra  
Community College, Fremont, Ohio



## Facilitators and Recorders

The following people functioned as either a Facilitator or Recorder at the national conference.

Cheryl Cleaves

Jan Hoeweler

Nancy Sattler

Ray Collings

Vern Kays

Gary Simundza

Lawrence Gilligan

Lynn Mack

Deborah Woods

Chuckie Hairston

Rodney Null

Michelle Younker

# CRAFTY Workshop Participants

The following people attended the October 5–8, 2000, CRAFTY workshop at Los Angeles Pierce College, Los Angeles, California, or the workshop at J. Sargeant Reynolds Community College, Richmond, Virginia, October 12–15, 2000.

## Biotechnology and Environmental Technology

**Brenda Breeding**, Professor of Biology,  
Oklahoma City CC, Oklahoma City,  
Oklahoma.

**Daniel R. Brown**, Lead Instructor of  
Microbiology and Biotechnology, Santa Fe  
CC, Gainesville, Florida.

**Sybil Chandler**, Lead faculty for the  
Environmental Health and Safety  
Technology Associate Degree program of  
Metropolitan CC's (MCC) Maple Woods  
CC, Kansas City, Missouri.

**Lois Dinterman**, Director of Bioprocessing  
for Biolex, Inc., Pittsboro, North  
Carolina.

**Linnea Fletcher**, Austin CC, Austin, Texas,  
and South Central Regional Director for  
Bio-Link

**Leland Grooms**, Adjunct faculty for  
Environmental Sciences, Maple Woods  
CC, Kansas City, Missouri.

**Elaine Johnson**, City College of San  
Francisco, San Francisco, California, and  
National Director for Bio-Link, an  
Advanced Technological Education (ATE)  
Center of Excellence of the National  
Science Foundation

**Wendie Johnston**, Pasadena City College,  
Pasadena, California: Program Director  
and Ed>Net Director

**JoAnne Marzowski**, Bristol Myers Squibb,  
Oncogene, Seattle, Washington.

**Donald McAfee**, Chair and CEO of  
Discovery Therapeutics, Inc., Richmond,  
Virginia.

**Jim McGillem**, Biomedical, Facility  
Director, St. Mary's Warrick Health Care  
Facility, Boonville, Indiana

**Lisa Seidman**, Biotechnology Program,  
Madison Area Technical College,  
Madison, Wisconsin; North Central  
Regional Director for Bio-Link

**William H. Woodruff**, Department Head,  
Biotechnology Department, Alamance  
CC, Graham, North Carolina, and  
Southeast Regional Director for the  
Bio-Link.

**Steve Yelton**, Program Chair, Electronics,  
Biomedical Electronics & Computer  
Network Engineering Technology,  
Cincinnati State Technical and CC,  
Cincinnati, Ohio.

## Electronics, Telecommunications, and Semiconductors

**David Baker**, Professor Emeritus, Rochester Institute of Technology/Past Chair of TAC of ABET, Kingsport, Tennessee

**Elizabeth Basinet**, President, Barrett Resource Group, San Diego, California

**Bob L. Bixler**, Workforce Consulting, Austin CC, Austin, Texas (Now at San Juan Basin Technical School, Cortez, Colorado.)

**Steve Cooperman**, Science Teacher Lecturer, Westridge School (high school), Pasadena, California

**Christopher Dennis**, Consultant, Steaming Kettle Consulting, Portland Community, Portland, Oregon College

**Linda Hollstegge**, Instructor, Information & Engineering Technology, Cincinnati State Technical & CC, Cincinnati, Ohio

**James Hyder**, F11X Training Developer (Thin Films), Intel Corporation, Hillsboro, Oregon

**Gerald Janey**, Chairman of Engineering Technology, Massasoit CC, Brockton, Massachusetts

**Rino Mazzucco**, Instructor, Department of Technology: Electronics, Mesa CC, Mesa, Arizona

**Lyle B. McCurdy**, Professor Electrical & Computer Engineering Technology, Dept. of Engineering Technology, California State Polytechnic University, Pomona, California

**John Palmer**, Professor of Manufacturing Engineering/Electronics Technology Program, Industrial/Electronics, Central Arizona College, Signal Peak Campus, Coolidge, Arizona

**James Payne**, Supervisor Tech Support & Management Systems, Oak Ridge National Laboratory, Oak Ridge, Tennessee

**Branislav Rosul**, Professor of Mecontronics, College of DuPage, Glen Ellyn, Illinois

**Tim Woo**, Instructor, Electronics/Engineering, Durham Technical CC, Durham, North Carolina

**Jim Wood**, Division Chair, Industrial & Engineering Technology, Tricounty Technical College, Pendleton, South Carolina

## Information Technology

**Connie Blackwood**, Director of Education and Research Initiatives, Idaho Engineering Laboratory, Idaho Falls, Idaho.

**Robert D. Campbell**, Chief Information Officer & Executive Dean of Information Technology Services, Rock Valley College, Rockford, Illinois.

**C. Fay Cover**, Director, Division of Learning Technologies, Pikes Peak CC, Colorado Springs, Colorado (Currently with Sun Microsystems).

**Robert Hillery**, Chairman, Information Systems Technology, NHCTC Pease International Tradeport Campus, Portsmouth, New Hampshire.

**Denecia Merritt-Damron**, Information Technology Division Director and Instructor of Desktop Applications Software, Marshall Community and Technical College, Huntington, West Virginia.

**Keith Morneau**, Assistant Professor, Information Systems Technology, Northern Virginia CC, Annandale, Virginia.

**Scott Nicholas**, MCSE and Instructor of Computer Networking, Marshall Community and Technical College,

Huntington, West Virginia.

**Randy Robertson**, Network Instructor, Wake Technical CC, Raleigh, North Carolina.

**Dan Schwartz**, Manager, Supply & Transportation Systems Development Group within IT, Marathon Ashland Petroleum, Findlay, Ohio.

**Dick Thomas**, Independent Database Consultant, Littleton, Colorado.

**Nancy Thomas**, Independent Database Consultant, Littleton, Colorado.

## Mechanical and Manufacturing Technology

**Ashok Agrawal**, Department Chair and Professor, Plastics Technology, St. Louis CC, St. Louis, Missouri

**Gregg Anderson**, Materials Engineer, Air Force Research Lab (AFRL/MLPJ) USAF, Wright Patterson Air Force Base, Dayton, Ohio

**Larry Earnhart**, Technical Leader, Performance, Polymers and Chemicals, Honeywell International, Inc., El Segundo, California.

**Mike Farley**, Marine Designer, National Steel and Shipbuilding (NASSCO), San Diego, California.

**Reece Gibson**, CNC Instructor, Metropolitan CCs, Kansas City, Missouri.

**Nick Johnson**, Technical Instructor, Bosch Automotive, Anderson, South Carolina.

**Tracy Koss**, Engineering Manager, Marathon/ Ashland Corporation, Findlay, Ohio.

**Jack Mclellan**, Quality Assurance Coordinator, Mott CC, Flint, Michigan.

**Gregory Meserve**, Professor of Manufacturing Technology, New Hampshire Technical CC, Berlin, New Hampshire.

**Bob Monter**, Technology Specialist, Wright Technology Network, Dayton, Ohio.

**John Reed**, Training and Development Specialist, ExxonMobil, Baton Rouge, Louisiana.

**Frank Rubino**, Professor and Chair, Department of Mechanical Civil/Construction Engineering Technology, Middlesex County College, Edison, New Jersey.

**Al Schwabenbauer**, Vice President, Sikorsky Aircraft, United Technologies Corporation.

**Jim Shimel**, Machine Tool Instructor, Metropolitan CCs, Kansas City, Missouri.

**Emin Turker**, Dean of Engineering Technologies, Lakeland CC, Mentor, Ohio (Currently Dean of Engineering Technologies, SUNY Canton, Canton, New York).

## Mathematicians

**Gayle Childers**, J. Sargeant Reynolds  
Community College, Richmond, Virginia

**Deborah L. Cohen**, John Tyler Community  
College, Chester, Virginia

**Susan Ganter**, Clemson University, Clemson,  
South Carolina

**Bill Haver**, Virginia Commonwealth  
University, Richmond, Virginia

**Mary Ann Hovis**, James A. Rhodes State  
College, Lima, Ohio

**Harvey Keynes**, University of Minnesota,  
Minneapolis, Minnesota

**Robert L. Kimball**, Wake Technical  
Community College, Raleigh, North  
Carolina

**Roland Moore**, J. Sargeant Reynolds  
Community College, Richmond, Virginia

**John C. Peterson**, Chattanooga State  
Technical Community College,  
Chattanooga, Tennessee

**Elizabeth Teles**, National Science  
Foundation, Washington, D.C.

**Gwen Turbenville**, J. Sargeant Reynolds  
Community College, Richmond, Virginia

**Bruce Yoshiwara**, Los Angeles Pierce  
College, Los Angeles California

**Kathy Yoshiwara**, Los Angeles Pierce  
College, Los Angeles California

**Susan Wood**, J. Sargeant Reynolds  
Community College, Richmond, Virginia

**Julia Woodbury**, J. Sargeant Reynolds  
Community College, Richmond, Virginia

## Project Evaluator

**George Vaughan**, Professor of Higher Education, North Carolina State University, Raleigh,  
North Carolina



# Advisory Committee

Seven people were members of the Advisory Committee. A short biography of each Committee member is below.

**Catherine C. Aust**, Head of the Department of Mathematics, Clayton College & State University, Morrow, Georgia. She is the representative to the Advisory Committee from the Mathematical Association of America (MAA).

**David Baker**, Professor Emeritus, Rochester Institute of Technology. Past Chair of TAC of ABET (Technology Accreditation Commission of the Accreditation Board for Engineering and Technology, Inc.)

Baker began his teaching career at the SUNY College of Technology in Alfred, New York, after receiving his undergraduate degree from Manmouth College of West Long Branch, NJ. While he pursued his graduate degree at the Rochester Institute of Technology (RIT), Baker continued teaching at SUNY. He earned his Master of Science degree in 1972.

In 1981, Baker left SUNY to become the Director of the School of Engineering Technology and a Professor of Electrical Engineering Technology at Rochester Institute of Technology, where he was responsible for overseeing 1300 students and 47 faculty and staff.

As a tireless supporter of engineering technology education, Baker has spent 25 years

striving to develop a niche for this emerging specialization. He has championed numerous initiatives to bring greater quality, diversity, and innovation to engineering technology programs and has also served as a leader in a number of professional societies, including the Institute of Electrical and Electronics Engineers (IEEE) and the American Society for Engineering Education (ASEE), where he chaired both the Engineering Technology Council and the Engineering Technology Leadership Institute.

**Elaine A. Johnson**, City College of San Francisco, Director of Bio-Link. BS Physical Science/Math, University of Minnesota, 1960; MA Biology/Microbiology, San Francisco State University, 1976; MS Biology/Clinical Nutrition, 1982; PhD, Educational Administration, University of Texas at Austin, 1997.

Johnson is the PI for the Bio-Link National Advanced Technological Education Center for Biotechnology and has participated in national efforts to improve mathematics education for students preparing for careers in the emerging technologies, particularly for biotechnology technicians.

**Arnold Packer**, Senior Fellow, Institute for Policy Studies, the Johns Hopkins University, Baltimore, Maryland.

Packer was executive director of the U.S. Labor Department's Secretary's Commission on Achieving Necessary Skills or SCANS. He is co-author of *Workforce 2000*, which, along with the SCANS reports, has altered the national conversation about human resource education. He has had a distinguished career in the federal government having worked for the U.S. Office of Management and Budget, the Senate Budget Committee, and as assistant secretary for policy, evaluation, and research at the U.S. Department of Labor. Dr. Packer holds a Ph.D. in economics from the University of North Carolina at Chapel Hill and a master's in business administration.

**John Reed**, President of The Learning Business, specializing in linking learning with business. Former Training and Development Specialist for ExxonMobil, Baton Rouge, Louisiana.

**Albert Schwabenbauer**, Aerospace Manufacturing Consultant. Former Vice-President, Planning at Sikorsky Aircraft, United Technologies Corporation. He has broad manufacturing and customer service executive background, having served as Vice-President, Manufacturing, and Vice-

President, Customer Service, over a 33-year career in aerospace.

Schwabenbauer holds a bachelor's and master's in Electrical Engineering from Rensselaer Polytechnic Institute, and a master's in Administrative Sciences from Yale University.

**Ronald Talley**, Department Head, Electronic Engineering Technology, Tri-County Technical College, Pendleton, South Carolina, and leader in the South Carolina ATE (Advanced Technological Education) Center.

Talley has three years experience in secondary education and over twenty-six years in postsecondary. He is presently head of the Electronic Engineering Technology Department at one of sixteen campuses in the South Carolina technical education system. He has been a member of South Carolina's Exemplary Faculty of Advanced Technological Education for the past three years, which is funded by the National Science Foundation. He was recognized as a distinguished educator by the Governor's Office in the State of South Carolina. Talley was named one-of-ten outstanding technical educators by the American Technical Education Association.

