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ABSTRACT

Between 1993 and 1996, Henry Ford Community College (Michigan) worked with business, industry, and technical instructors to revise their Technical Mathematics program in accordance with the National Council of Teachers of Mathematics (NCTM) Standards. The purpose of the project was to restructure the technical math curriculum and create a context for cooperation between vocational faculty and mathematics faculty. The project team was involved in a variety of activities that included visiting job sites, developing and revising learning activities, attending curriculum revision meetings, piloting and evaluating the curriculum, and disseminating project results. An effective system of creating partnerships with business and industry was also developed. As a result, activities were created that focused on topics such as Method Summary Charting and creating a safe work environment. Industry partners and an independent reviewer positively critiqued these activities, but technical math instructors were less positive. Group projects, discussions and computer activities were a central part of course revision. Students in the revised courses demonstrated better problem solving skills than those in traditional courses, but student retention was better in the traditional program. Appendices include revised course content, a sample computer activity, and other sample activities. (YKH)

A Revision of Technical Mathematics Based on the NCTM Standards

Final Report:
Fund for the Improvement of Postsecondary Education Grant

Barbara Near

Fund for the Improvement of Postsecondary Education

COVER SHEET

Grantee Organization

Henry Ford Community College
Mathematics Division
5101 Evergreen Road
Dearborn, MI 48128

Grant Number

P116B31816

Project Dates

Starting Date: September 1, 1993
Ending Date: June 1, 1996

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FIPSE Program Officer

Joan Krecji

Grant Award

Year 1: $45,300
Year 2: $44,200

SUMMARY

The purpose of the project was 1) to restructure the technical mathematics curriculum according to the NCTM Standards, and 2) to create a context for cooperation between career faculty and mathematics faculty in the redesign of curriculum and development of applied problems. The project team developed several activities and then incorporated those activities into the technical mathematics curriculum. To allow sufficient time to complete the activities and to make the courses more relevant, the course content was significantly revised. An experimental/control group design was used for project evaluation.

Students in the revised curriculum scored higher on the problem solving test than did students in the control group. Basic skills scores were approximately the same for both groups. Retention was lower in the experimental group.

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EXECUTIVE SUMMARY

Project Title: **A Revision of Technical Mathematics Based on the NCTM Standards**

Grantee: **Henry Ford Community College, 5101 Evergreen, Dearborn, MI 48128**

Project Director: **Barbara Near (313) 845-6467**

Project Overview:

For over 20 years Henry Ford Community College has offered Technical Mathematics for students in 2-year career programs. This sequence was in serious need of reform. The project focused on reforming this sequence in accordance with the NCTM Standards. The project team worked with business, industry and technical instructors to develop the revised curriculum and create related learning activities. Instructors also worked to change the delivery of course content. Group projects, discussions and computer activities were a central part of the course. Preliminary evaluation results are mixed. While students in the revised curriculum outscored students in the traditional program, the retention rate in the revised program was lower than in the traditional program.

Purpose:

The purpose of the project was 1) to restructure the technical mathematics curriculum according to the NCTM Standards, and 2) to create a context for cooperation between career faculty and mathematics faculty. As the project developed we understood that we were tackling the same problems that faced many other educators in the metropolitan Detroit area. So we became actively involved in Tech Prep and the Southeast Michigan Association for Reform of Technical Education (SMARTE).

Background and Origins:

The Mathematics Division has been involved in the revision of the liberal arts sequence of courses for several years. But this project was the first systematic effort to improve the technical mathematics curriculum. Although many of the goals for revising the tech courses were the same as our goals for the liberal arts courses the context was very different. Working closely with the technical faculty and business and industry was both challenging and rewarding. Creating a meaningful curriculum that was within the grasp of technical students was difficult.

Project Description:

The project team was involved in a variety of activities that included visiting industry, developing and revising learning activities, attending curriculum revision meetings, piloting and evaluating the curriculum and disseminating project results. Creating partnerships with business and industry was very time consuming. But as the result of this project we developed a system that is quite effective. As a result of these partnerships we developed activities that focus on topics such as Method Summary Charting and creating a safe work environment.

Evaluation:

The project evaluation included 1) a critique of the activities, and 2) the assessment of student learning. Our industry partners and an independent reviewer critiqued the activities. They were very positive about the activities. The activities were also distributed to tech math instructors in various parts of the country. These instructors were less positive about the activities.

In assessing student achievement we compared students who were in the revised courses to those taking the traditional courses. Students in the revised courses demonstrated better problem solving skills. Students in both groups had similar basic skill levels. Student retention was better in the traditional program.

Summary and Conclusions:

The project team gained insights involving working with business, implementing a reform curriculum with nontraditional students, using the computer as a teaching tool and the mathematics skills essential for technical students. When working with business it is important to take a proactive role. Most business contacts don't know the mathematics skills used by technicians. Determining those skills and creating appropriate learning activities is dependent on finding the right business partner and persistent follow up. Because technical students often must balance the many demands of their personal, work and academic lives and because they often lack the most basic technical knowledge it is difficult to implement a reform curriculum that focuses on group work projects and real life problems. Real life problems must be "scaled down" to be within reach of students, and the course must be designed to accommodate frequent student absences. Our project used the computer as a tool for aiding student discovery. Students who have always learned mathematics by lecture have to develop the skill of discovery. At first discovery activities must be carefully structured to "lead" the student to the correct conclusion. Careful debriefing of discovery activities is a must. Lastly, we learned we teach technical students far too much algebra and far too little geometry and statistics.

PROJECT OVERVIEW

For over 20 years Henry Ford Community College has offered Technical Mathematics for students in the following 2-year programs; CAD, manufacturing, computer science, electronics and automotive.. Tech Math consisted of 3 traditional lecture courses, Math 100, Math 103 and Math 106. These courses focused on basic arithmetic, algebra, geometry and trigonometry. Like most Tech Math offered nationwide our sequence had received little attention and was in serious need of reform. Therefore, we proposed a revision of Tech Math based on the NCTM Standards.

The project team consisting of 4 mathematics instructors and 2 technical instructors worked with business, industry and other technical instructors to determine the mathematics skills and problems that are most important for technical students. Based on this work we revised the basic course content. The team then developed problem solving and computer Activities that formed the basis of the reformed courses. The team ran a pilot involving approximately 200 Math 100 and Math 103 students. The pilot instructors used a variety of teaching methods including brief lectures, group projects, discussions and computer explorations.

Preliminary evaluation results are mixed. Math 100 students in the pilot (experimental) group performed better on a problem solving test than did students in the traditional (control) group. Math 103 students in the pilot sections showed some improvement in problem solving. With the exception of geometry the experimental groups performed as well or better than the control groups on basic skills tests. The success rate (grade of C or higher) was lower in the experimental sections.

PURPOSE

Nature and Significance of the Problem

Seven years ago, the publication of Toward a Lean and Lively Calculus (1986) launched a significant reform of the nation's calculus curriculum, but no comparable reform had been introduced in technical math, *the only college math taken by approximately 100,000 of the nation's community college students prior to their entry in the workplace*. Although the calculus reform movement was broadened to include all mathematics instruction by the National Council of Teachers of Mathematics (NCTM) with the publication of Curriculum and Evaluation Standards for School Mathematics (1989) and Professional Standards for Teaching Mathematics (1991), little had been done to incorporate these standards in technical math. The NCTM Standards recommend that all math students should engage in inductive problem-solving and work in "technologically rich environments that open a new array of real-world problems to mathematical solution" (Mathematical Association of America 6). Ironically, technical math students too often faced a curriculum that consisted of rote learning, formula-driven exercises, and limited access to recent technological advances that enhance learning in mathematics.

With the publication of reports such as "America's Choice: High Skills or Low Wages," national commissions have underscored the need for vocational students to obtain a solid understanding of mathematical concepts in order to compete in an ever-changing and increasingly technological economy. Yet, most mathematical curricular initiatives focused on the content and pedagogy of the nation's liberal arts mathematics curriculum. To address this oversight, we proposed a pilot program to reform the nation's technical math courses in accordance with NCTM Standards. Integral to this project was the creation of Activities, rooted in real life applications, that could easily be disseminated to other community colleges.

Objectives

The purpose of the project was 1) to restructure the technical math curriculum to incorporate the Standards enunciated by the NCTM, and 2) to create a context for cooperation between College career education faculty and mathematics faculty in the redesign of this course and in the development of applied real life problems that can be used as course material. Our objectives were as follows:

1) To incorporate NCTM standards into HFCC's technical math sequence,

2) To stimulate valuing and understanding of the nature and usefulness of mathematical reasoning,

3) To promote valuing and understanding of the constructive interplay between mathematics and technology,

4) To promote collaborative learning and independent problem solving,

5) To increase retention of students in technical math classes,

6) To more accurately and fairly assess student performance by using portfolio assessment,

7) To assist other community colleges by creating application packets that can easily be disseminated, and

8) To disseminate our results to the nineteen school districts that are HFCC partners in a Tech Prep Consortium.

Current Understanding of the Problem

Soon after we began our work we realized the project was growing, almost beyond our control. Due to the increased emphasis on School-To-Work, members of the educational community were eager to learn about any program related to training the work force. We were not prepared for this interest in our project. We had just started the project and had more questions than answers. Some mathematics educators called expecting the magic solution to curriculum revision. We had numerous invitations to visit community colleges to talk about our project that was in its infancy. We were also invited to attend meetings sponsored by Tech Prep and other consortiums. Had we attended every meeting and accepted every invitation our development time would have been severely cut. But we did think it was important to collaborate with educators outside our college, even in the early stages of our project. This was a change in our initial plan.

The Project Director became a member and attended all meetings of Southeast Michigan Association for Reform of Technical Education, SMARTE. SMARTE, a consortium of high schools, community colleges, universities and corporations is working to coordinate efforts in technical education and to support curriculum reform. Another member of our team attended local Tech Prep meetings. Through these associations we were able to learn more about training the work force. We also learned that many technical educators are unsure about the direction education should take. They seem overwhelmed by Tech Prep, School-To-Work, Work Force 2000, The Scans Report, Charter Schools, etc.

Because we were the only community college mathematics instructors attending these meetings we thought it was important to, in some small way, influence these groups. For example, one phrase often used in conjunction with mathematics was, "just in time learning." Many of the technical educators thought all mathematics skills should be taught just before they were needed in a technical course. They further believed only those mathematics skills directly applicable to a career course should be taught, and they should always be taught in an applied context rather than in the context of other mathematics. These views are not consistent with the NCTM Standards. Skills must be taught with an emphasis on conceptual understanding and always in terms of the big mathematical picture. This is even more important now when it is predicted most people will change careers several times within their lifetime. Students need math skills that can be transferred to other career areas. Most community college technical and career faculty were unaware of the NCTM Standards. So our goals expanded to include informing the educational and business communities about the NCTM Standards and their importance.

The success of our project relied heavily on being able to find real life problems that involved mathematics. At the time we wrote the proposal we thought this would be fairly easy. We now know this is not the case. We had anticipated visiting corporations and walking away with a plethora of problems that would easily work into Activities. This did not happen. We had to struggle to get appointments and then struggle to extract any mathematics from the day to day operations of business and industry. Therefore one of our major goals became defining a procedure for developing a relationship with business that could eventually lead to useful Activities.

BACKGROUND AND ORIGINS

Origins

The College has always offered a variety of mathematics curricula. The Mathematics Division offers a liberal arts sequence including developmental and college transfer courses. The Mathematics Division also offers a technical sequence that serves students in a variety of career programs. A third set of applied courses is offered by the Trade and Apprentice Division. These courses are intended only for those students enrolled in trade and apprentice programs. Since the Trade and Apprentice Division operates on a calendar different than the calendar for all other College divisions, they are almost a separate school.

For the past decade the Mathematics Division spent a considerable amount of time developing and improving the liberal arts curriculum. Technology and more problem solving were integrated into these courses. A variety of inservices were offered for instructors. The Division continues this work today. The related trades faculty also recently revised and improved their courses. The Technical Mathematics sequence however, has received little attention during the last ten years. The goals of the courses varied depending on the teacher. At best the sequence was a watered down version of the liberal arts sequence. Some effort was made to communicate with technical instructors to elicit suggestions for improving the sequence but this was a sporadic, uncoordinated effort.

Through the curriculum work on the liberal arts sequence the Mathematics Division became aware of the importance of the NCTM Standards. Since the standards stress problem solving, real life application, cooperative learning and using technology, they formed a perfect foundation for the revision of the Technical Mathematics Sequence. The Standards emphasize many of the same goals business and industry consider important for its employees. So our previous curriculum development and the need for reform in technical mathematics generated this project.

Context

Because our project would directly impact technical students we wanted to work closely with instructors from the Technical Division. We initially encountered some hostility from the technical instructors. This was probably due to our past neglect of the technical courses. By the end of the project our relationship with technical instructors was greatly improved. We wanted to know those mathematics skills technical instructors considered most important. Determining those skills was nearly impossible because there was little or no agreement even among instructors who taught the same technical course. Some technical instructors rated even the most obscure skills as extremely important. Others rated only a few skills as extremely important. Some thought mathematics courses should focus on problem solving and critical thinking, but others thought a plug and chug course would be sufficient. Trying to reach consensus with all instructors would have been too time consuming. We decided to work closely with one technical instructor to determine a list of the essential skills to be taught in the sequence. He shared this list with the other instructors and based on their feedback we made refinements.

In order to develop real life problem solving Activities we needed to work with business and industry. This was the biggest challenge of the project. We planned to work with members of the College Advisory Boards. Some advisory board members were unwilling to help us and those who were willing had little or no idea how mathematics is used on the job. We had to spend weeks making new partners. Our new business partners were enthusiastic but since they were volunteers it was difficult to set up initial meetings and follow up visits. In some cases our partners worked on high security projects so we needed special permission or security clearance before we could schedule a meeting. Occasionally a partner would have to curtail his or her work on the project due to lack of support from a supervisor.

Of course the students were a very important part of this project. Even though team members have many years experience working with the diverse student population of a community college, we overestimated what our students would be able to accomplish. Technical students tend to be older and have more family and job related responsibilities than do our other students. We originally planned to give students some class time to work on projects. Then the projects were to be completed out of class. However, the majority of the students had demanding schedules that made it impossible for them to schedule out of class time to complete group projects. We decided to allow more class time for completion of the projects but this meant we had to reduce the content of the course. Student absences were also a problem. Often the class worked on a project for several days. If a student missed a day or two it was difficult for the group to function. We tried a variety of approaches to correct this problem including allowing students to change groups, allowing students to work individually and assigning shorter one day activities. None of these approaches were completely successful.

Working with students in the more advanced classes provided another challenge. These students were interested only in their career area. If a project involved some other technical area they thought it was a waste of their time to work on the project. At the time we thought it was important for students to see how mathematics could be used in a variety of careers. So even though the students grumbled we required them to complete a variety of projects.

In the second and third year of the project we faced a problem we had not anticipated, a dramatic decline in enrollment. The technical area suffered the most. Although we don't know the reason for the decline in college wide enrollment we may know why the decline was greater in our technical courses. Since fewer four-year schools are giving transfer credit for technical courses students are reluctant to take these courses. Also our SMARTE and Tech Prep colleagues tell us anything labeled technical is considered undesirable by parents who think the American Dream means being a doctor, lawyer or engineer. Parents are not aware of the excellent opportunities in technical careers and therefore don't encourage students to pursue these careers. We are presently investigating ways to encourage students to take our technical courses.

Even though several of our experimental sections had low enrollment the college has shown its support for the project by allowing us to run experimental sections with less than the minimum class size. We did have to cancel the third course (Math 106) in the sequence. The enrollment was five. Since this class runs once a year we won't be able to pilot any of the materials until the 1996-97 academic year.

The project took place in the context of a large division consisting of 18 members and offering over 100 sections per semester. In many ways the Division was supportive of the project. They allowed us to experiment freely with the technical courses. The experimental sections were very different in both delivery and content. Based on the findings of this project the Division has decided to change the course content in all Tech Math courses. The amount of routine algebra was reduced and replaced with more applications, geometry and statistics. See Appendix A. Several instructors who were not part of the original project team have used <u>some</u> of the Activities in their classes.

Although instructors have willingly changed course content and included some of the Activities in their classes there is no interest in totally changing the classroom delivery system to one that focuses on group work and laboratories. We suspect there are many reasons for this lack of interest. First, radical change takes time. Second, those of us who have made this change look exhausted (we are) and our offices are filled with weird things like Styrofoam swimming pools, rice, resistors, pipe cleaners and gum drops. Who would want to follow in our footsteps! Third, we were so busy writing and testing activities we were unable to actively promote change. Fourth, even though we have some preliminary data that shows this method may be beneficial we don't have conclusive proof. And there is considerable evidence this method could decrease retention.

PROJECT DESCRIPTION

The team was involved in various types of activities - writing computer Activities, visits to industry, meetings with technical instructors, curriculum revision meetings, piloting Activities, inservicing instructors and evaluation of the project. These Activities are described below.

1. <u>Writing Computer Projects</u> Two of the mathematics instructors were responsible for writing the computer Activities. Since Interactive Physics and the Geometer's SketchPad were the latest packages on the market, the instructors had to learn to use the programs before the writing could begin. MathCad and Logo were well known software packages so no learning time was necessary. After an Activity was written it was given to the member of the team with the least computer experience. Acting like a student she did the Activity. Then, in her role as an instructor, she corrected any errors and enhanced the Activity. This process resulted in Activities that were virtually error free and very user friendly. All forty Activities focused on skills deemed important by industry. (Examples in Appendix B)

2. <u>Visits to Industry</u> One of the team members was responsible for contacting industry partners. She set up appointments and wrote an agenda for each meeting. Along with the agenda she sent a sample Activity. The agenda was very important because it helped to keep the meeting focused. The sample Activity was the best way to illustrate the goals of the project. Usually two or three other team members went on the visits. We talked to supervisors and observed technicians as they worked. When we returned to campus we created learning Activities based on the visit. These Activities were then sent to the industry partner for

corrections and suggestions. The Activities were rewritten several times prior to use in the classroom. We developed 5 major Activities, each consisting of several problems. These major Activities cover the Making of Glass, Method Summary Charts, the Lifting Equation, the Coordinate Measuring Machine and Statistics in Industry. Numerous other shorter Activities were also developed. These Activities focused on topics such as wind tunnels, robotics, designing a sunshade, manufacturing dental products and estimating for construction. We also developed several 3-D geometry laboratories. (Examples in Appendix C)

3. Meetings with Technical Instructors At the beginning of the project the project director met with course leaders from the technical area. She described the project and asked instructors to submit examples of the uses of mathematics in their courses. Many examples were sent, but most involved simple plug and chug algebra. The team worked with these examples and created activities that required more problem solving. After the initial meeting the two technical instructors served as liaisons between the team and the technical area. They surveyed all technical instructors to determine those mathematics skills most important in technical studies. Unfortunately there was no agreement on these skills even amongst instructors who taught the same courses! Since the survey produced little valuable information, one liaison met with instructors individually. They were able to reach some consensus as to the most important skills.

4. Curriculum Revision Meetings In January 1995 a Technical Mathematics Committee was formed. Since all members of the Division teach Tech Math from time to time we wanted to include instructors who were not involved in the project. The committee consisted of three of the team members and three other mathematics instructors. Based on the input from industry and the technical instructors the goals of the courses were revised.

5. Pilot Program In September 1994 team instructors began piloting Activities in the first two courses, Math 100 and Math 103. Based on the first semester trial some of the Activities were revised. Many of the original Activities were too long and complicated. In January 1995 the team members ran a second pilot. In September 1995 a section of the first course was piloted by an instructor who was not a member of the team.

6. Inservice Activities Two of the team members offered four inservice sessions. The presenters showed instructors how to use the computer equipment and the software packages. The industry visits and related Activities were discussed.

7. Evaluation Activities The team members were constantly involved in program evaluation. These Activities are described in the section that follows.

8. Dissemination Activities We presented at seven conferences. We shared preliminary evaluation results and sample Activities.

EVALUATION

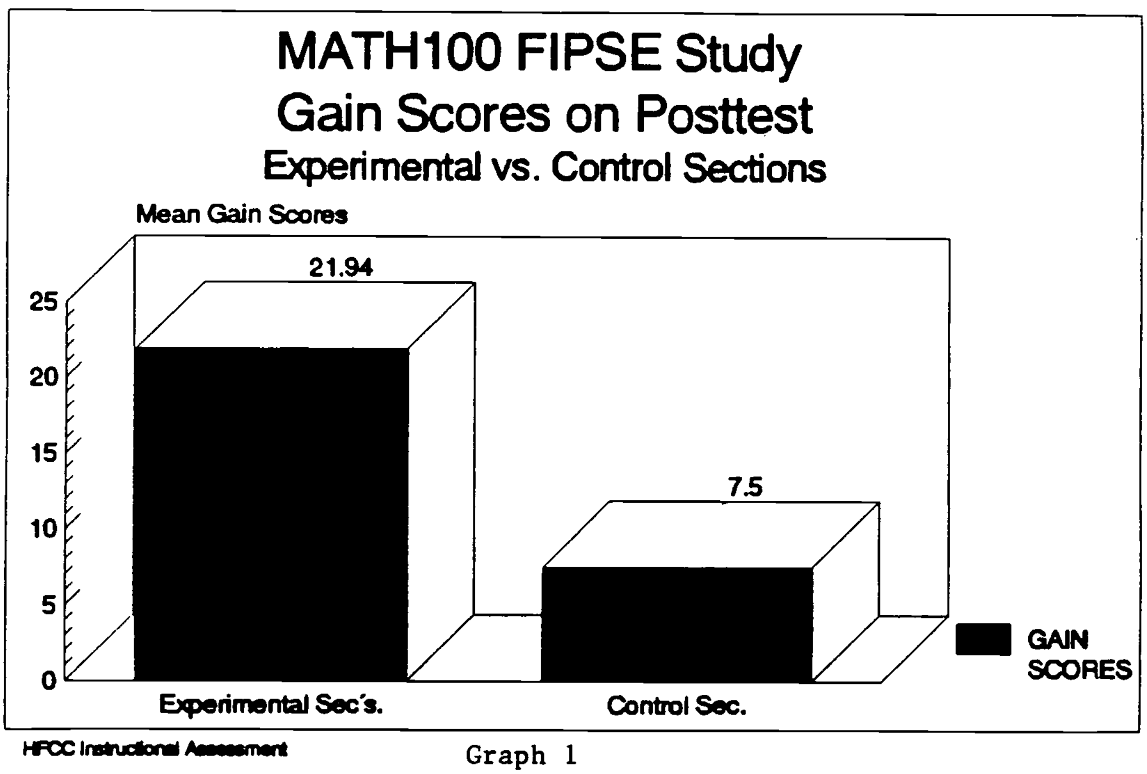
The evaluation involved review and critique of the Activities and assessment of student learning. This evaluation and our plans for the future are discussed in this section.

1. Evaluation of Activities Selected Activities were evaluated by our industrial partners. In all cases these evaluations were very good. In one case the evaluator was so impressed with the Activities he wanted to distribute them nationwide before they were field tested. Another

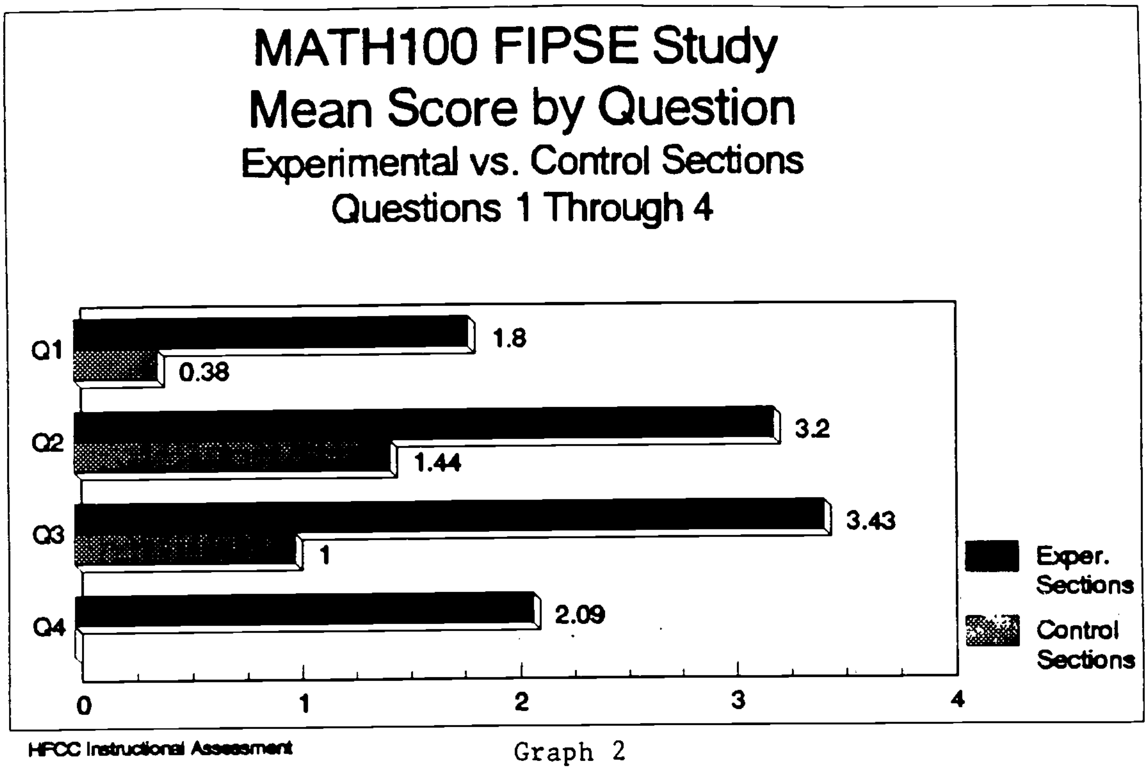
evaluator commented enthusiastically that the authors had included many aspects of mathematics he considered to be very important to this work. He was very surprised and pleased the team could identify these skills after just one visit. Sample activities were also given to an expert in mathematics education. Her evaluation was also very positive. She gave a poor rating to only one Activity. The team agreed this Activity was poor and eliminated it.

Last year Addison Wesley distributed some of the Activities to mathematics instructors nationwide. Some of the reviewers said there is a need for real life problems, but others said the Activities were not mathematics. This is true. We found no technicians who just did mathematics. Mathematics was always a part, sometimes a small part, of a problem that involved many other disciplines.

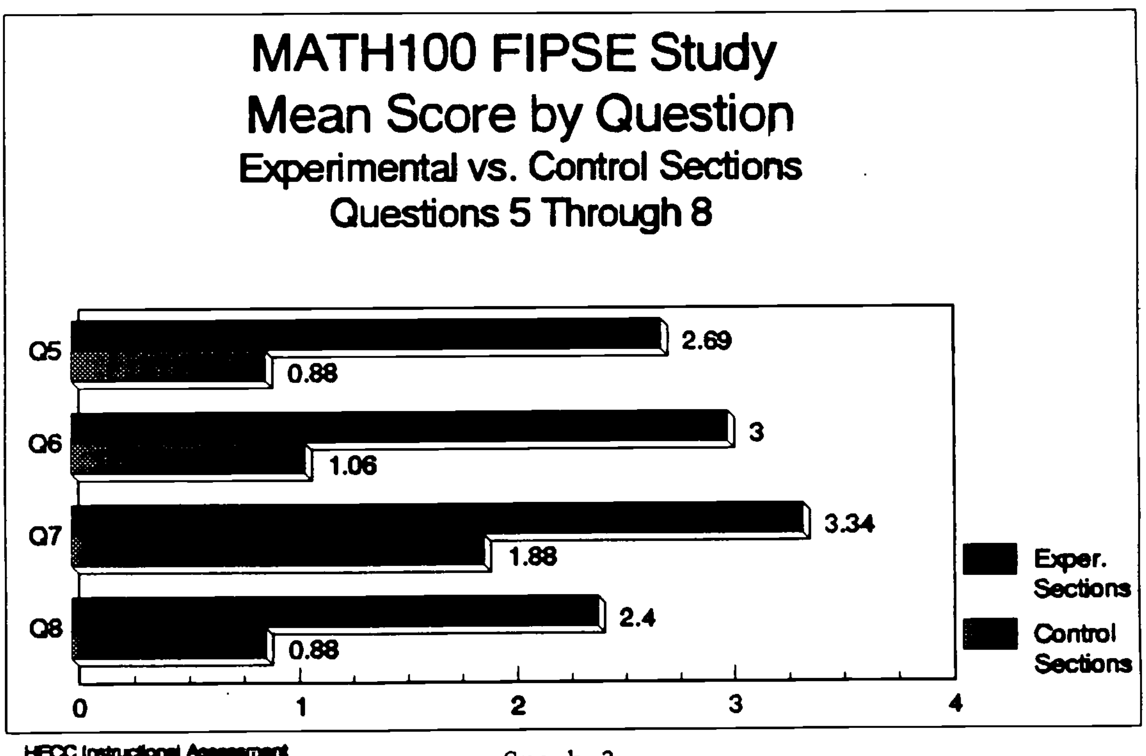
2. Student Assessment Our study compared the achievement of students in the pilot or experimental sections to the student achievement in the traditional or control sections. We first tested the Math 100 materials in the fall 1994 and winter 1995 semesters. Students in both groups took a pre and post problem solving test. The gain scores are shown in Graphs 1- 3. Students in the experimental group scored significantly better.



Graph 1

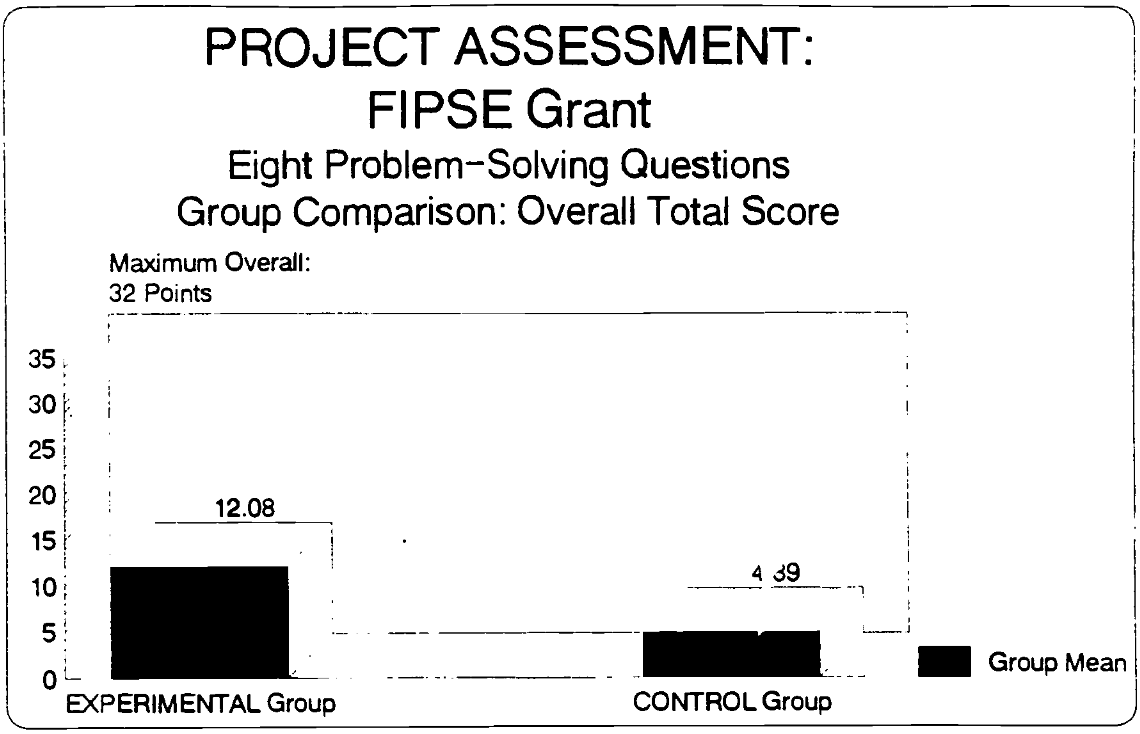


Graph 2



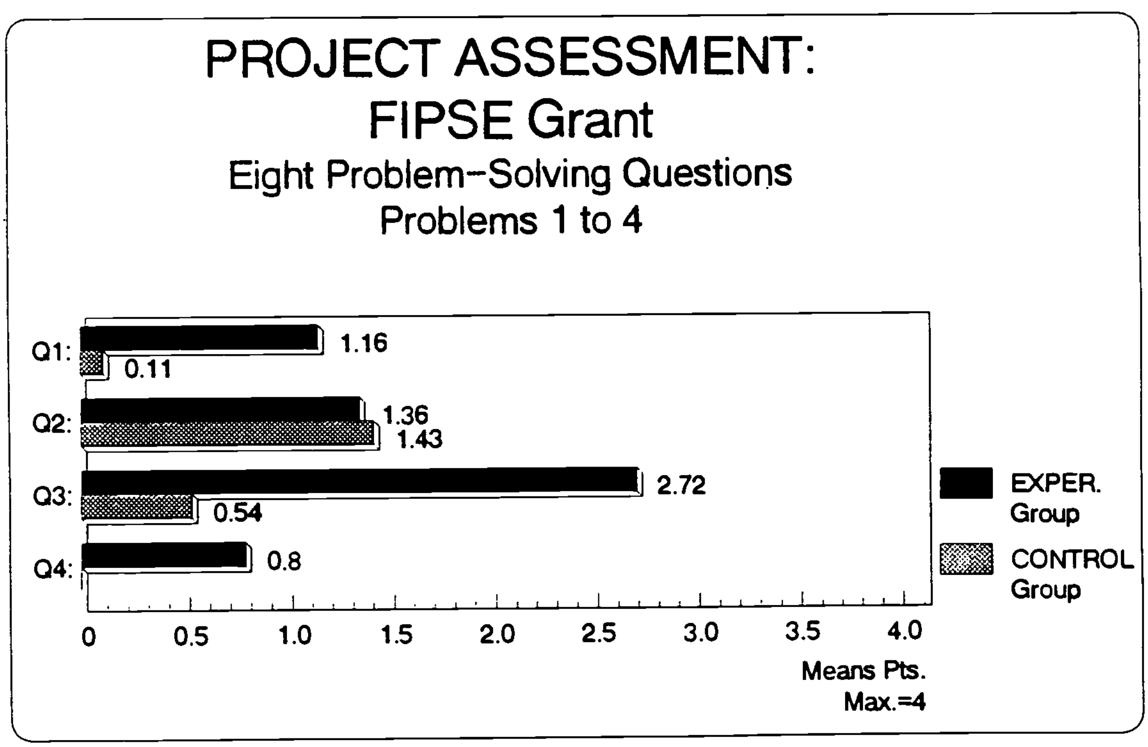
Graph 3

We ran another evaluation of Math 100 in fall 1995. This time we used only the problem solving post test because scores were so low on the pre test of the first evaluation. We also gave a post test on basic algebra and geometry skills. A comparison of the experimental and control groups is shown in graphs 4 - 7.



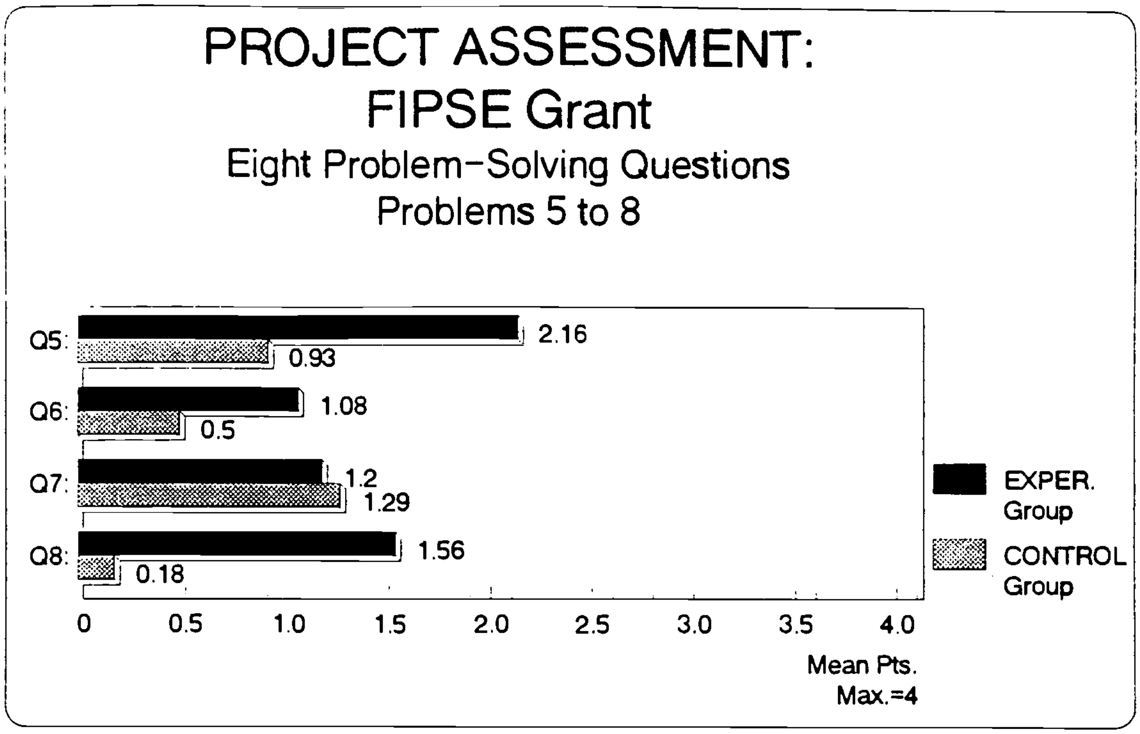
HFCC Instructional Assessment

Graph 4



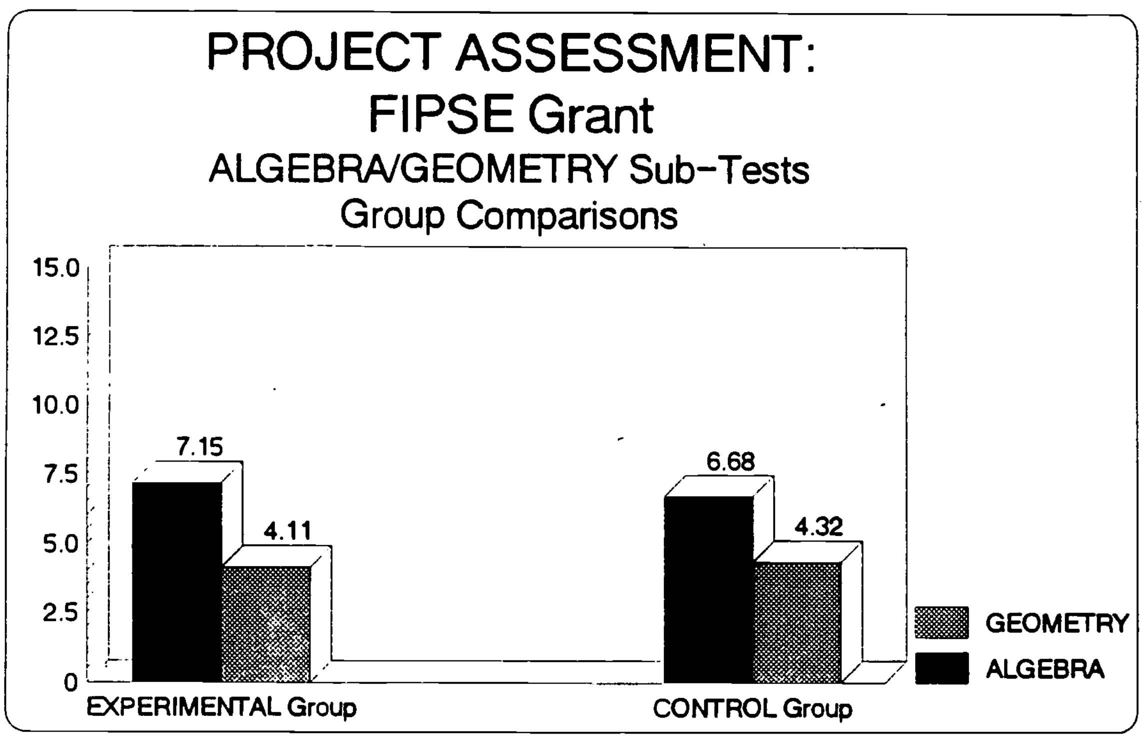
HFCC Instructional Assessment

Graph 5



HFCC Instructional Assessment

Graph 6

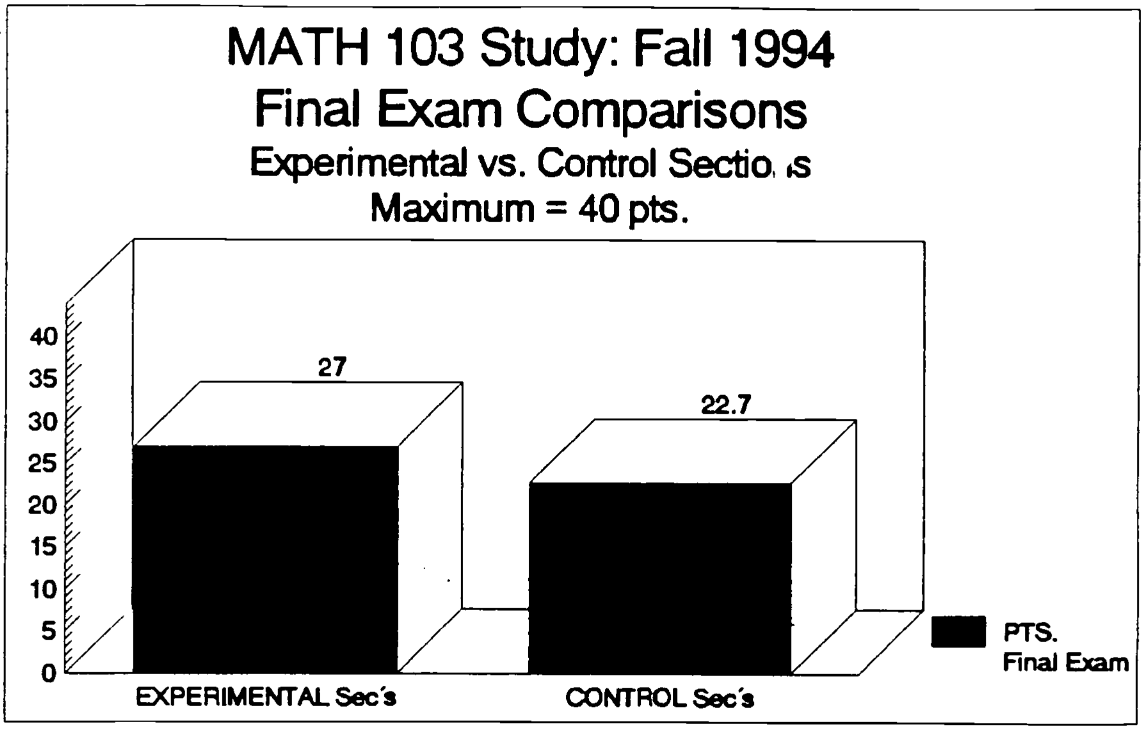


HFCC Instructional Assessment

Graph 7

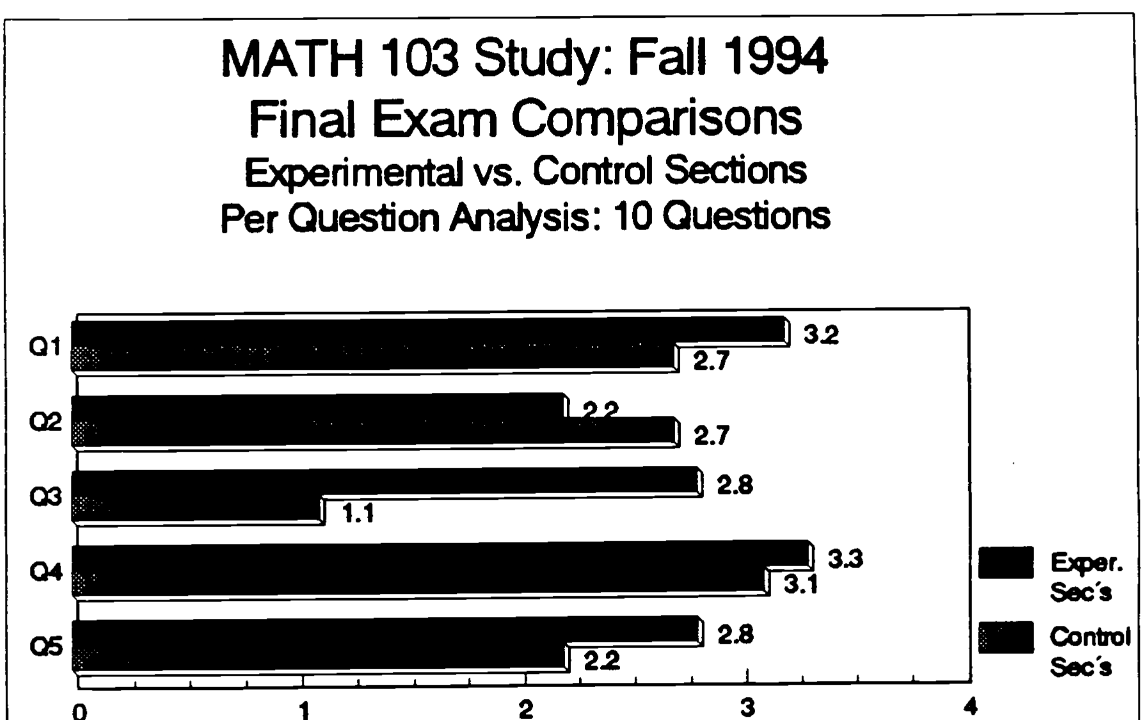
Again, students in the experimental group performed better in problem solving. There was little difference in algebra performance. Students in the control group performed better on basic geometry. One section of the experimental section was taught by a non-team instructor. Her students scored lower on the problem solving test than did the students in the section taught by the team member.

In the second course (Math 103) both the experimental and control groups were given a post test covering basic algebra and trigonometry skills. A comparison of the achievement is shown in graphs 8 - 10.



HFCC Instructional Assessment

Graph 8



HFCC Instructional Assessment

Graph 9

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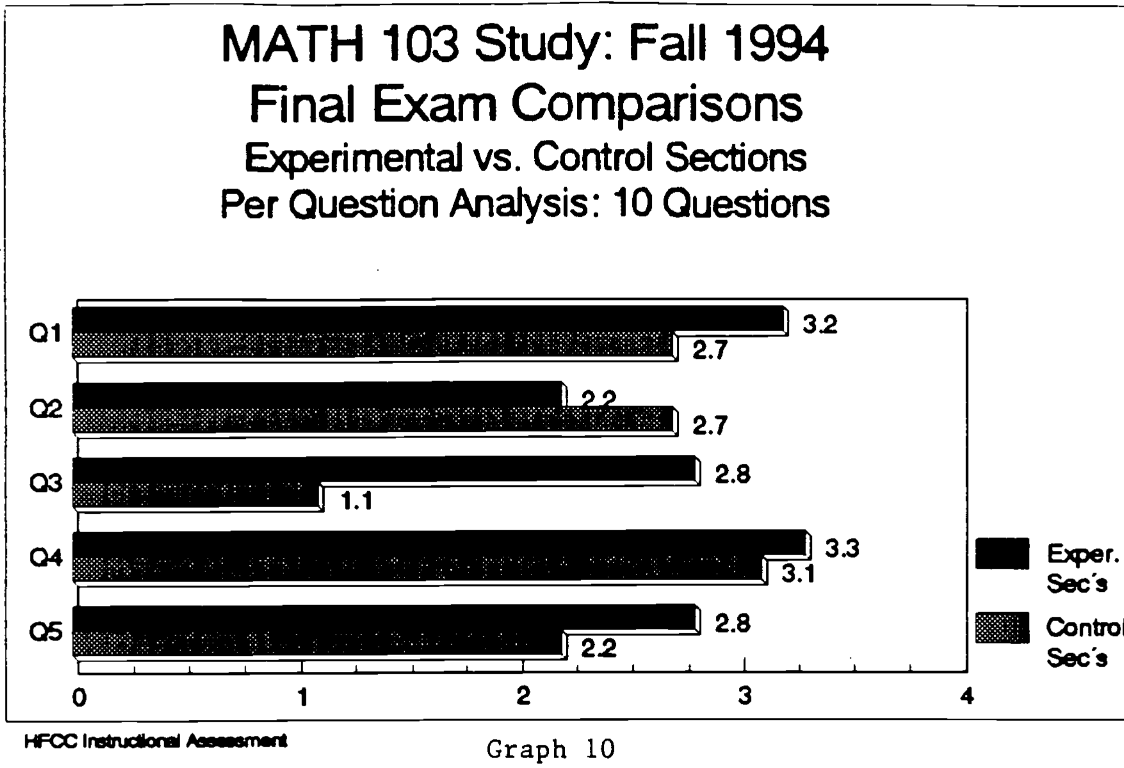

Graph 10

Since the experimental Math 103 group was small we can't conclude the experimental method produced greater achievement in basics but it appears the experimental method did not interfere with the learning of the basics.

Since the Math 103 problem solving Activities were fairly long and in many cases involved, the computer, a problem solving post test was not practical. Therefore, the problem solving skills of the Math 103 students in the experimental group were assessed by examining student portfolios. The students in the control group did not have portfolios because they only did problems from the traditional textbook. While all students in the experimental group showed some improvement in problem solving, in most cases the improvement was minimal. In general, students progressed from not being able to even begin a multiple step problem to being able to produce disorganized solutions that contained some errors. Two students showed significant progress. This was probably due to their interest in the computer.

As part of the evaluation we also examined retention rates in the control and experimental groups. In the Math 100 control groups, 58% of the students earned credit (a grade of C or better) in the course. In the experimental groups, 33% of the students eamed credit. While we were disappointed in these results we think there are some logical reasons for the lower pass rate in the experimental course. First, the experimental Math 100 is more difficult than the traditional course. Second, when a student misses a day of the traditional course he or she can read the book and do the problems at home. But when a student misses a day of the experimental course it is difficult to duplicate the experience at home. Therefore, many students were behind the class schedule and eventually gave up.

In the Math 103 control group, 58% earned credit. 50% of the experimental group earned credit. Since the experimental group was small, initial enrollment 17, it is impossible to determine whether there was any real difference in these pass rates. We think it is too early to draw any definite conclusions regarding the success or failure of the experimental method. We plan to continue our evaluation in the fall of 1996. Since we will not have any funding we are going to concentrate on one course at a time. In the fall we will run another experimental session of Math 100. Prior to that time we will redesign the Activities and look for ways to increase the pass rate without lowering the standards.

3. Plans for Continuation During the 1996-97 academic year we will run another evaluation of the Math 100 course. We will also develop an interdisciplinary (electronics, mathematics and English) course. Many of the Math 103 activities will be used in this course. The students in this course will take a traditional Math 103 course. They will do the applied problems as part of the interdisciplinary course. This may reduce the amount of student grumbling pertaining to the requirement of projects that have nothing to do with their major. In addition, only the math instructor involved in the interdisciplinary course will be responsible for teaching by the project method. This may be better than forcing all Math 103 instructors to incorporate the projects.

   We will continue our involvement with SMARTE. The Project Director is presently working on a SMARTE project focused on defining the skills that are necessary for product designers. We plan to disseminate our work through SMARTE.

   We will continue to work with Tech Prep to encourage more students to pursue technical careers. We had one meeting with local high schools and plan to schedule others.

SUMMARY AND CONCLUSIONS

If we were to begin this project tomorrow we would have a much better idea of how to "get it right." Throughout the project we made mistakes but those mistakes led to many valuable insights. Those insights involve working with business and industry, implementing a reformed curriculum with non-traditional students, using the computer as a tool for doing and discovering mathematics, and determining the essential mathematics skills.

Working With Business and Industry

From our experience we have formulated a list of Do's and Don'ts for developing successful partnerships with business and industry.

Don't count on existing college advisory boards for help. Often members of advisory groups only rubber stamp programs.

Do ask friends, family, colleagues and professional associations for names of potential partners.

Don't count on a great deal of assistance from managers when developing Activities. They are too far removed from technicians.

Do look for partners who have been involved in training or who work in a laboratory. Former teachers make excellent partners.

Don't make the initial contact yourself.

Do ask the office of the president or vice president to make the initial contact.

Don't plan to develop any Activities by just touring a plant. You won't obtain enough specific information.

Do send a new partner an agenda for your first meeting. Include a list of specific questions and a sample Activity. We found the meetings need to be tightly focused if they are to be productive.

Don't plan just one visit to a particular site.

Do plan to return to every site with an Activity that your partner can edit.

Don't underestimate the amount of time it will take to develop a productive partnership.

Don't expect every meeting to be productive.

Do exercise patience but keep in touch with partners who have not contributed. Gentle nagging can pay off.

Working With Nontraditional Students

Our students worked an average of 30 hours per week, but several worked 50-60 hours per week. On average they were taking 3 courses. Most have family responsibilities and some were single parents. Because of the many demands in their lives, many of the students had to miss several classes. Our original course expectations were unrealistic. It was impossible to expect students to meet in groups outside of class. We partially solved this problem by giving students more class time to work in groups. But this did not solve the problem of frequent student absences. When we offer Math 100 in the fall we will create a more flexible classroom that will accommodate the special needs of our students.

Requiring students to solve real life problems presented us with an unforeseen challenge. Many of the students in Math 100 knew so little about the real world they had trouble with even the simplest real life application. We learned that every real life problem had to be preceded by a simpler related problem. An example is given in Appendix D.

Using Computers in Technical Mathematics

Our original plan was to use MathCad as a tool for problem solving in Math 103. This was very difficult and we will change this part of the project in the future. When working with students individually it became clear that the students had trouble with MathCad because they did not have a good understanding of basic algebra. They needed to do more problems by hand before using this powerful tool. Without knowing about the trouble we had encountered with MathCad, one of our corporate partners encouraged us to require students to understand how to solve problems by hand before letting them use the computer to do the problem. He thought working through problems by hand gave the student a better understanding of the problem.

In Math 100 we used the computer as a tool for exploration. For many of the students it was very difficult to explore, make a hypothesis and then test the hypothesis. Students often developed a false hypothesis and then thought they confirmed this hypothesis. Others would develop a trivial hypothesis and miss the really important concept. We found the Activities had to be fairly structured to lead the student to a correct and useful hypothesis. Even then a careful debriefing was necessary to eliminate false conclusions.

Essential Mathematics Skills

At first we were very reluctant to eliminate any content from the courses. But our study confirmed our suspicions that we teach far too many unnecessary skills. Students in technical programs need to understand measurement, 2-D and 3-D geometry, graphs, very basic algebra, basic trigonometry, statistics (including SPC) and coordinate geometry (including rectangular and polar coordinates). We found no need for topics such as complicated factoring, operations with polynomials and rational expressions, complicated equation solving, graphing complicated equations and trigonometric identifies. This list could go on and on. We have reduced the algebra content in Tech Math and replaced this content with more geometry and statistics. We could probably eliminate even more content but it is very difficult to eliminate topics that instructors have taught for years.

The Need for Balance

When we first started this project we envisioned a completely transformed curriculum and delivery system. Upon reflection the need for a balance between the old and the new seems to be a better goal. We believe students still need to do a certain amount of rote plug and chug to be successful when attacking a project. We also believe when properly structured, and not overused, plug and chug can lead to insights. We also see a need for some traditional lecture in the delivery system. Lecture is still a good way to teach certain basic facts quickly and efficiently. With lower level students a lecture can be useful when the class loses focus.

This project has certainly forced us to reflect on what we teach and how we teach. We certainly don't know what works best but the process has been both challenging and exciting.

APPENDIX A

Revised Course Content

MATH 100

CATALOG DESCRIPTION:

This course is intended for students in technology programs who have not had one year of algebra and one year of geometry or who need to review beginning algebra and geometry. Topics covered include a review of arithmetic, an introduction to the scientific calculator, introduction to statistics, working with approximate numbers and dimensional analysis. The course focuses on algebraic and geometric topics emphasizing technical applications.

COURSE OBJECTIVES:

1. Review of arithmetic and introduction to calculator

2. Introduction to fundamentals of statistics, algebra and geometry to provide background for further technical courses.

3. Application of arithmetic, algebra, geometry, and statistics to technical areas.

COURSE CONTENT:

Basic Operations with Numbers
Ratio, Proportion, and Percent
Use of Calculator
Measurement and Approximate Numbers
Descriptive Statistics
Algebraic Expressions
Linear Equations and Inequalities
A Brief Introduction to Factoring
A Brief introduction to Exponents, Roots and Radicals
A Thorough Introduction to Geometry (include some 3-D)
Measurement of Plane and Solid Figures
An Introduction to Right Triangle Trigonometry

MATH 103

CATALOG DESCRIPTION:

This course is intended for students in technical programs. Topics include a review of basic algebra and the use of the calculator, functions and graphs, the trigonometric functions, systems of linear equations, determinants, quadratic equations, vectors, solutions of triangles, statistics, an introduction to polar coordinates, and integer exponents. This course emphasizes practical technical applications.

COURSE OBJECTIVES:

1. To introduce trigonometric functions and provide proficiency in algebraic and trigonometric computations for problem solving in technical areas.

2. To provide additional mathematical background for further technical courses.

3. To develop skills using electronic calculator.

COURSE CONTENT:

Units of Measure, Approximate Numbers, and the Calculator
Fitting Curves (especially Lines) to Experimental Data
Operations in Algebra
Functions and Graphs
The Trigonometric Functions
Systems of Linear Equations; Determinants
Factoring (briefly); Solving Quadratic Equations and Using the Quadratic
Formula (Do NOT solve by completing the square!)
Trigonometric Functions of Any Angle; Introduction to Polar Coordinates
Vectors and Oblique Triangles
Additional Topics in Statistics

MATH 106

CATALOG DESCRIPTION:

Topics covered include exponents, radicals, complex numbers, logarithms, exponential functions, systems of nonlinear equations, variation, graphs and properties of basic trigonometric and polynomial functions, analytic geometry, and further use of statistics.

COURSE OBJECTIVES:

1. To increase skill in solving problems algebraically.
2. To increase and extend proficiency in algebraic and trigonometric computations for problem solving in technical areas. The applications are from typical situations in industry, business and electronics.
3. To provide essential mathematical background for further technical courses.

COURSE CONTENT:

Elementary Operations with Exponents and Radicals
(Simple radical equations included)

Complex Numbers

Exponential and Logarithmic Functions
Deemphasize log properties and using log properties to solve equations)
Emphasize solving single equations and graphing on logarithmic scales)

Graphs of Sine and Cosine Functions

Additional Topics in Trigonometry

Systems of Equations
Equations of Higher Degree } Emphasize Graphical Solutions

Variation

Plane Analytic Geometry

Further Topics in Statistics

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APPENDIX B

Sample Computer Activity

ACTIVITY 12: CENTRAL ANGLES, INSCRIBED ANGLES, AND THEIR MEASURES

Software Package: Enhanced 2.01

File: Enhanced

Objectives

This activity is designed to introduce you to two types of angles that are constructed within (on?) circles. After completing this activity, you should be able to:

- find the measure of an arc knowing the measure of the central angle that intercepts it (and vice versa)

- find the measure of an arc knowing the measure of the inscribed angle that intercepts it (and vice versa)

- find the measure of a central angle knowing the measure of an inscribed angle that has the same points on its rays

ACTIVITY

1. Using the circle tool, draw a circle.

2. Using the point tool, mark 2 new points on the circle.

3. Using the text tool, label these points and the center of your circle.

4. Using the segment tool, draw an angle with the three labeled points. Use the center of the circle as the vertex. (This is a central angle.)

5. Click on . Then click on any white space on the screen.

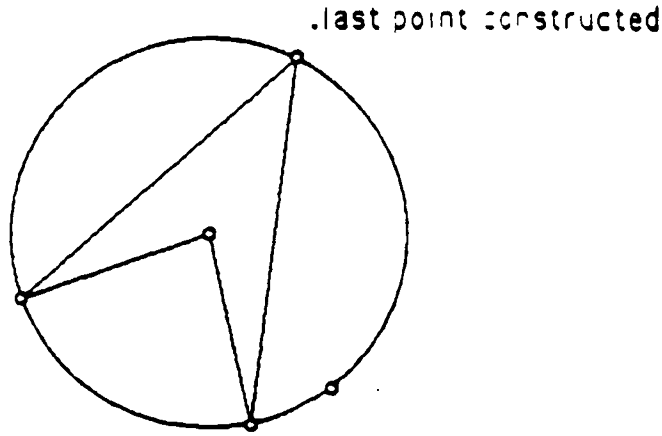
6. Measure the angle. (You must highlight your three points with the vertex as the second point highlighted. Then use the measure menu to highlight angle.)

7. Measure the arc intercepted by this angle. To do this, highlight the circle and the 2 labeled points on the circle. Using the measure menu, highlight "measure arc angle".

8. What do you notice about the measure of the central angle and the intercepted arc? Drag one of the 2 points around the circle to change the size of the angle. How do the measures of the arc and central angle compare?

9. With the point tool, mark a 3rd point on the circle. Label it with the script tool.

10. Using the segment tool, construct an inscribed angle using the last point constructed as the vertex. (see below)



11. Measure the inscribed angle. What do you notice about the measure of the inscribed angle and the arc it intercepts? Drag any of the three labeled points on the circle to change the size of the inscribed angle. How do the measure of the inscribed angle and arc compare? How do the measure of the inscribed angle and the central angle compare?

SUMMARY

Look back at the objectives and quiz yourself. have you learned all that the objectives stated?

Write a short paragraph describing what you learned. Include definitions and pictures.

ACTIVITY 13: CONSTRUCTIONS USING CIRCLES AND THEIR ASSOCIATED ANGLES

(Teacher Notes)

Teacher Preparation

This activity is based on the knowledge gained from the previous activities.

Software Package: Geometer's Sketchpad (Enhanced 2.01)

File: Enhanced

Objectives

This activity is designed to have the students apply their knowledge of triangles, quadrilaterals, and circles. After completing this activity, students should be able to construct a

- right angle
- equilateral triangle
- rhombus
- perpendicular lines
- square
- octagon

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ACTIVITY 13: CONSTRUCTIONS USING CIRCLES AND THEIR ASSOCIATED ANGLES

Software Package: Enhanced 2.01

File: Enhanced

Objectives

This activity is designed to have you apply your knowledge of triangles, quadrilaterals, and circles. After completing this activity, you should be able to construct a

- right angle
- equilateral triangle
- rhombus
- perpendicular lines
- square
- octagon

ACTIVITY

PART I: Constructing a Right Angle

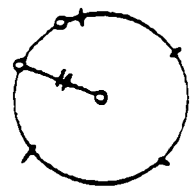
1. Draw a circle
2. Using only the segment tool, construct a right angle.
   a) Describe the method you used.
   b) How do you know this method guarantees the angle is a right angle (no measuring allowed)?
3. You can hide any parts of the sketch you don't want to see. Click on the part to highlight it. Use the display menu to highlight "hide".

PART II: Constructing an Equilateral Triangle

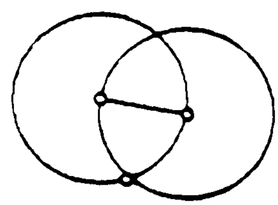
1. Draw a circle. With the segment tool, construct a radius.

2. Construct a second circle with the same radius as the first and centered at the endpoint of the radius you just constructed. To do this,

   a) highlight the radius of your circle and the endpoint of the radius.



   b) using **construct menu**, highlight circle by radius and center.



3. Using this sketch and the segment tool, construct an equilateral triangle.

   a) Describe the method you used.

   b) How do you know this is an equilateral triangle (no measuring allowed).

PART III: Constructing a Rhombus

1. Construct a figure like the one you did in Steps 1 and 2 above.

2. Using this figure and the segment tool, construct a rhombus.

   a) Describe the method you used.

   b) Without measuring, how do you know this is a rhombus?

PART IV: Constructing Perpendicular Line Segments

1. Using one of your previous sketches, construct perpendicular line segments.

2. Describe your method.

3. Without measuring, how do you know these are perpendicular?

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PART V: CONSTRUCTING A SQUARE

1. Draw a circle.

2. Draw a diameter (with the segment tool).

3. Draw a line perpendicular to this diameter passing through the center of the circle. To do this,

   a) highlight the diameter and the center of the circle,

   b) using the **construct** menu, highlight "perpendicular line." This will construct a line through the highlighted point perpendicular to the highlighted line.

4. Use this drawing and the segment tool to construct a square.

   a) Describe the method you used.

   b) How do you know this is a square (no measuring allowed)?

PART VI: CONSTRUCTING AN OCTAGON

1. Using Steps #1-3 in constructing a square and several additional steps, construct a regular octagon.

2. Describe the process you used.

APPENDIX C

Sample Activities

TEACHERS GUIDE TO MATH 103

PROBLEMS FROM INDUSTRY

DIMENSIONING, TOLERANCING, LAYOUT, AND THE COORDINATE MEASURING MACHINE

Any product that is mass produced must have consistent characteristics. In today's technological world, products such as computers, automobiles, or airplanes contain many small parts. These parts must be made to the utmost precision. This precision is critical to producing quality products and to producing interchangeable parts.

In this learning package, students will complete layout problems similar to the problems done in industry. The math skills necessary to complete this set of activities are the abilities to:

- do precise measurement
- use the rectangular coordinate system
- find the equation of a line using 2 data points
- compute with decimals
- find the equation of a hole given data points
- use MathCad to solve a system of simultaneous equations.

ACTIVITY 1

This activity is designed to have students measure the drawing of a rectangular plate and associate ordered pairs to various points on the plate. This is known as coordinatizing. The students will then locate holes on the plate and label the centers of these holes in a manner that works for them.

A discussion of proper layout techniques then guides the student in the correct method of laying out details on the plate. Tolerance stack up is discussed. The students are told to layout the part one more time using the desired method. A comparison of the two layouts is then made.

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ACTIVITY 2

A second layout activity is presented. Students are to find the equation of a line that passes through the centers of 3 holes. The solution is $y = 1.5$.

ACTIVITY 3

This activity has students check four parts to determine whether the part is made to specifications. Location and size of holes must be considered.

ACTIVITY 4

On many parts a hole is placed on the part to be used as a reference point. All dimensions on the part are measured from the center of this hole.

To simulate this procedure, Activity 4 has the students use the center of hole A as the origin of a coordinate system. Measuring from this point, students are to coordinatize the corners of the part.

Parts c and d will have the students locate the center of circle B and the point of intersection of the diagonals of rectangle c. Remind the students of the limitations of their measuring instruments.

ACTIVITY 5

This activity consists of 5 problems. MathCad will be used to help the students with tedious calculations.

An introduction to the activities reviews the equation of a circle and the use of this equation in industrial applications. The five problems that follow address equations of circles, error, and finding equations given data sets. Students will need to determine whether they are given enough data to solve a problem, and how to deal with a situation when too much data is given.

DIMENSIONING, TOLERANCING, LAYOUT, AND THE COORDINATE MEASURING MACHINE

When parts are being made for any type of assembly work, they must be made precisely. When new designs are engineered, a precise method of measuring is essential. During the production process, sample parts are taken and measured. These measurements are done to insure the accuracy of the machines producing the parts. During production, drill bits or other parts can wear. This causes a change in the size of the parts produced. If these parts no longer meet specifications, they cannot be sold.

Throughout the history of manufacturing, many different tools have been used to measure parts. In the early 1990's a computerized machine, the Coordinate Measuring Machine, is considered a state of the art measuring tool. It allows engineers to measure parts to an incredible degree of accuracy. As the name indicates, the CMM establishes a coordinate system and all points on the part are measured according to this coordinate system.

When making measurements the degree of accuracy that we use depends on the tool that we are using for our measurement. When measuring with a common ruler that has a millimeter scale, the error in our reading would be ±0.5 mm. Using tools such as the CMM can lead us to believe that we are measuring to incredible degrees of accuracy. The questions arise, "Are all of these numbers on the readout meaningful? What is the size of the unit to which we are measuring?"

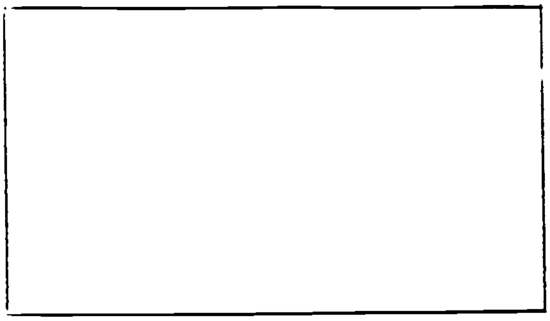
When a measurement is read from the CMM, several digits appear on the computer screen. When measuring in millimeters, using three digits to the right of the decimal point is considered world-class measuring. All digits further to the right are disregarded.

The Cross Company in Fraser, Michigan has created a comparison of units. In this comparison, the end of a hair is magnified 2000 times. Various units are then compared to this hair. Examine this comparison at the end of the learning package.

Let's examine several problems that simulate the use of the CMM. Some problems will involve your measuring, drawing, and computing. Other problems will involve the use of computer software to help with the computations. Have fun and good luck!

ACTIVITY 1

Suppose a rectangular plate must be measured to insure proper size and proper placement of four holes. The plate must measure 70.0 mm by 50.0 mm with a tolerance of ±0.5 mm, the center of the holes must be 5.0 mm ± 0.5 mm from either edge, and the holes must measure 4.0 mm ± 0.5 mm in diameter.



Create a rectangular coordinate system so that the origin is at the lower left hand corner of the plate. If the rectangle is made to the exact specifications, what would be the ordered pairs of the 4 vertices? Label the diagram.

The CMM has a stylus or probe located at the end of a robot arm. Using a joy stick, the engineer moves the stylus until it touches the spot to be measured. An ordered pair appears on the computer screen. This ordered pair gives the location of the point with respect to the coordinate system the engineer has chosen. If the rectangle is <u>exact</u>, the ordered pairs are A(0, 0), B(70.0, 0), C(70.0, 50.0) and D(0, 50.0).

Assuming that the angles are 90°, what is the range of values for the x-coordinates of B?

What is the range of values for the coordinates of C and D?

Draw a plate that is within tolerance but does not have the exact dimensions 50.0 mm x 70.0 mm. Locate the holes on your drawing. How did you do this?

Suppose this plate must fit over a part that measures 49.8 mm x 70.3 mm. This part has holes for fasteners. The holes must match up exactly with the holes on the plate. The coordinates of the centers of the holes are at (7.2, 7.1), (64.8, 7.2), (64.8, 43.0), and (7.2, 43.0). Assume the holes are within tolerance. Will the plate that you drew fit this part? Draw the part and the plate, cut them out, and see if fasteners will fit through the holes when the part and plate are fit together.

How did you layout your part? Did you use a coordinate system and measure all points from the origin? Did you draw the part and locate points by measuring from the edge?

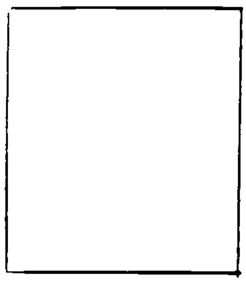
A common mistake in doing a layout is to measure important points from the edges of the part. If these points are necessary for the part to fit with another part, there may be a tolerance "stack up". A tolerance stack up means that the size of the plate is within tolerance, and the size and position of the hole is within tolerance. Combining these tolerances gives a larger than desired error. That is, when measuring off an edge that is not the origin in the coordinate system, the error from the edge and the hole might cause the hole to be so far off its desired position that the plate will not fit the part.

The correct layout method is to create a coordinate system and measure all important points from a specific point, usually the origin. In doing this, tolerance stack up is avoided. Critical points, such as points for positions of holes, will be better placed.

Reconsider the layout discussed above. Position a coordinate system conveniently on the part and give data points that specify the corners of the part and the centers of the holes. Is your plate closer to the desired size?

ACTIVITY 2

A steel plate has been designed to fit between two parts. This plate will be secured by three fasteners. We want to locate the holes for these fasteners.



The plate measures 30.0 mm x 35.0 mm. The fasteners are to be placed down the middle of the plate (lined up vertically). The diameter of the holes will be 3.0 mm and the holes must be spaced evenly so that the centers of the holes close to the top and bottom of the plate have y-coordinates of 6.5 mm and 28.5 mm, respectively. Using a ruler with a millimeter scale, draw in the holes on the plate above. Mark as precisely as you can the location of the center of each hole.

When you measured the distances, how did you do it? Did you choose a reference point from which to work? Did you mark your diagram as on a blueprint?

What was the distance, from center to center, between the holes on the edge and the middle hole?

The Coordinate Measuring Machine is designed to create or overlay an x, y coordinate system on a part to be measured. All points are then described as ordered pairs measured from an origin. If we were going to use the CMM to measure the steel plate, the lower left hand corner of the plate would be a convenient spot to place the origin.

a) What ordered pairs represent the 4 corners of the plate? What are the units of the x and y coordinates?

b) Locate the centers of the holes using ordered pairs.

c) Draw in the holes using a diameter of 3.0 mm.

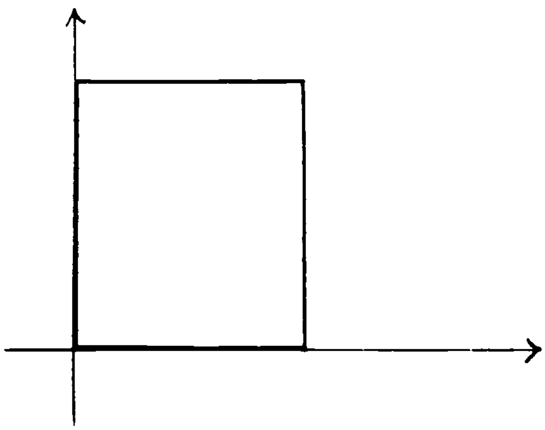
When mass producing parts such as this steel plate, workers will check the parts with the CMM to be sure that the plate is the correct size, that the holes are positioned correctly, and that the size of the hole is correct. One procedure is to find the equation of a line on which the centers lie. Do that for the holes you have drawn.

If your holes are drawn accurately, lines 1.5 mm to the right and to the left of the determined line should touch the holes in one point. Why? Draw those lines carefully and check your work. Are your circles close to the 3.0 mm size?

Doing this work by hand is quite cumbersome and somewhat artificial. Because of the crude measuring instruments, and thickness of our pen lines, we cannot work with the precision of computer software. Using more advanced mathematics can also change the procedure that we would use to test the quality of our product.

ACTIVITY 3

A box of steel plates have been sent to be quality checked. The diameter of the holes must be within ±.5 mm of the size on the print. The holes must be positioned so that the centers are within ±.3 mm of the desired x and y coordinates. The print of the part is below.



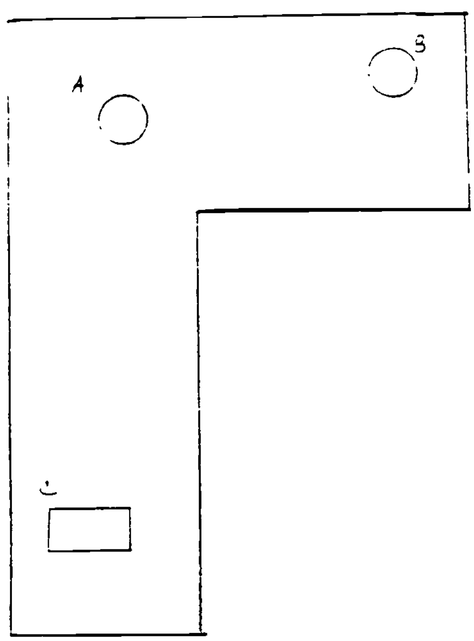
The measurements are labeled as they will appear in the chart. Check each part to determine if it is within the expected tolerances. Write a flow chart or outline of the steps you used.

Part Number	Reading 1	2	3	4	5	6
Desired Values from Spec	(13.5, 25)	(15, 25)	(16.5, 25)	(13.5, 10)	(15, 10)	(16.5, 10)
part #1	(13.4, 25)	(15, 25)	(16.6, 25)	(13.4, 10)	(15, 10)	(16.6, 10)
2	(13.2, 25)	(14, 25)	(15.2, 25)	(13, 10)	(14, 10)	(15, 10)
3	(13.2, 25)	(15, 25)	(16.8, 25)	(13.1 10)	(15, 10)	(16.9, 10)
4	(13.5, 25)	(15, 25)	(16.5, 25)	(13.5, 9)	(15, 9)	(16.5, 9)

These holes are very small. How do you think they will be used?

ACTIVITY 4

To help engineers measure a part, the part may have a special hole bored in it. The center of this hole is used as the origin of the coordinate system used to check the part. When visiting the Ford Motor Company's Scientific Research Laboratory, an intricate transmission casing was being measured. A special hole was cast within the casing and the CMM was measuring all other details of the part using the center of this hole as the origin of the coordinate system. Let's use this idea to measure some parts that are less complicated than a transmission casing!



The diagram to the left is the face of an automotive part. The hole A is drilled into the part for dimensioning purposes.

a) Using the center of the hole as the origin of a coordinate system, find the coordinates of all corners of the part.

b) Find the distance from the center of hole A to the center of hole B.

c) Find the distance from the center of hole A to each corner of rectangle C.

d) Find the distance between the center of hole B and the center of rectangle C. (You will have to use some geometry to find this center.)

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ACTIVITY 5

Introduction

You will recall the equation of a circle with center (h, k) and radius r is

$$(x - h)^2 + (y - k)^2 = r^2.$$

In previous exercises you were given an equation of a circle. You then graphed the equation by finding the center and radius and plotting points.

In many "real life" applications we reverse this process. We start with points on the circle and use these points to find an equation of the circle. For example, find an equation of the circle that passes through the points (-3, -2), (4, 5) and (5, 4).

First: We know the equation can be written in the form $(x-h)^2+(y-k)^2 = r^2$. We must determine the values for h, k and r.

Second: We know each of the 3 given points must satisfy this equation. So we can obtain 3 equations in 3 unknowns (h, k and r) by substituting the given values for x and y into the basic equation. We obtain:

when $x = -3$, $y = -2$	$(-3 - h)^2 + (-2 - k)^2 = r^2$
when $x = 4$, $y = 5$	$(4 - h)^2 + (5 - k)^2 = r^2$
when $x = 5$, $y = 4$	$(5 - h)^2 + (4 - k)^2 = r^2$.

Third: Using MathCad, we solve the above system of simultaneous equations (keeping in mind $r > 0$).

h := 0   k := 0   r := 2   given

$$(-3 - h)^2 + (-2 - k)^2 = r^2$$

$$(4 - h)^2 + (5 - k)^2 = r^2$$

$$(5 - h)^2 + (4 - k)^2 = r^2$$

$$\text{find}(h,k,r) = \begin{bmatrix} 1 \\ 1 \\ 5 \end{bmatrix}$$

We find $h = 1$, $k = 1$, $r = 5$.

Finally: The equation is $(x - 1)^2 + (y - 1)^2 = 25$. The circle has center (1, 1) and radius of 5 units.

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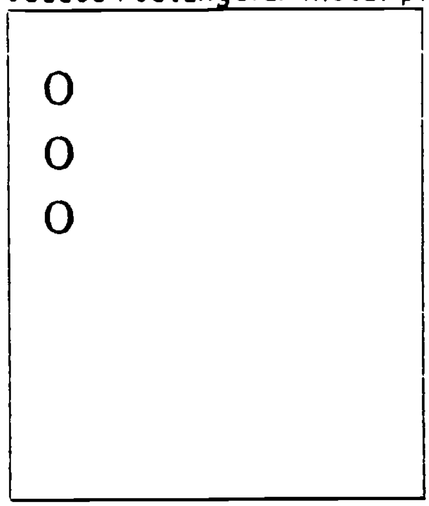
PROBLEM 1

A company produces rectangular metal plates like the one shown below.

3 "identical circular" holes



h = distance from top of plate to center of first hole

d = distance from center of hole to edge of plate

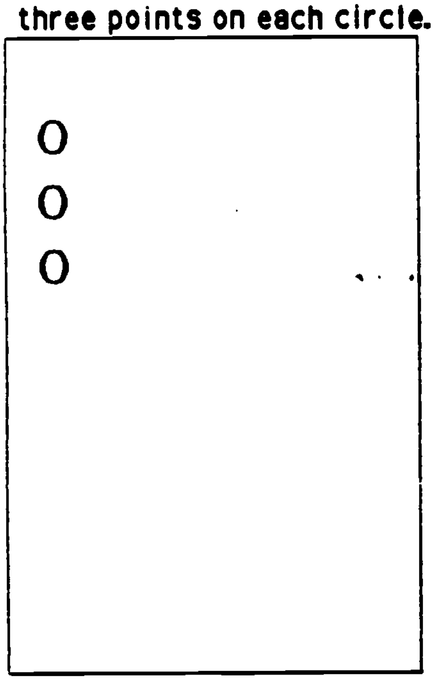
r = radius of hole

b = distance between centers of holes

Because these plates will fit with other metal pieces in a machine, the holes must be drilled within the following ranges:

$14.9 \text{ mm} \le h \le 15.1 \text{ mm}$
$14.9 \text{ mm} \le d \le 15.1 \text{ mm}$
$4.9 \text{ mm} \le r \le 5.1 \text{ mm}$
$8.9 \text{ mm} \le b \le 9.1 \text{ mm}$

A technician selects a plate from the assembly line and tests it to determine whether it meets these requirements. Using a coordinate measuring machine she takes readings from several points on the plate. She records the coordinates of three points on the edges of the plate. Next she records the coordinates for three points on each circle. The origin is at the lower left corner of the plate.

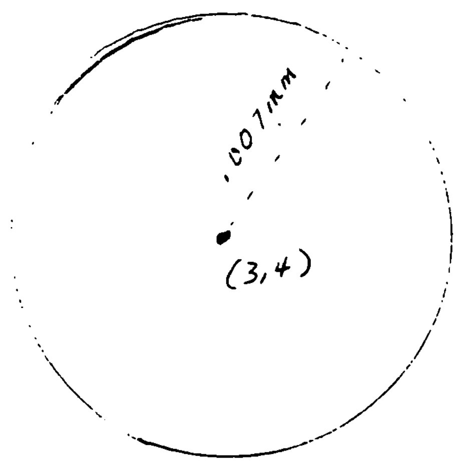


points on edges: (in mm)	(8.215, 105.000)
	(0.000, 70.000)
	(0.000, 17.500)
hole 1: (in mm)	(11.000, 93.148)
	(13.000, 94.681)
	(18.000, 94.112)
hole 2: (in mm)	(12.000, 77.113)
	(14.001, 76.193)
	(17.002, 76.516)
hole 3: (in mm)	(11.050, 75.196)
	(14.900, 77.081)
	(18.210, 75.940)

Use the above information to determine whether or not the holes are positioned correctly. Include a copy of your MathCad notebook. Write a brief paragraph summarizing your findings.

PROBLEM 2

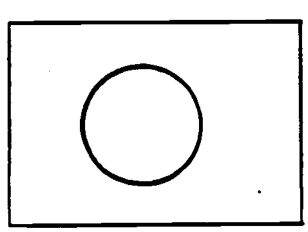
Although very accurate, the CMM does not give "perfect" measurements. If the technician obtains a reading of (3,4) for the coordinates of a point, the actual point could be anywhere in the circle with center (3,4) and radius of 0.007 mm as shown below.



In light of this new information, can you be sure the holes (problem 1) are positioned properly? Include a copy of your MathCad notebook. Write a brief paragraph summarizing your findings.

PROBLEM 3

In the process of making a part, a hole is drilled in a sheet of metal. A technician must determine upper and lower bounds for the area of this hole. He takes readings from 3 points of the edge of the hole. The origin is at the lower left corner of the plate.

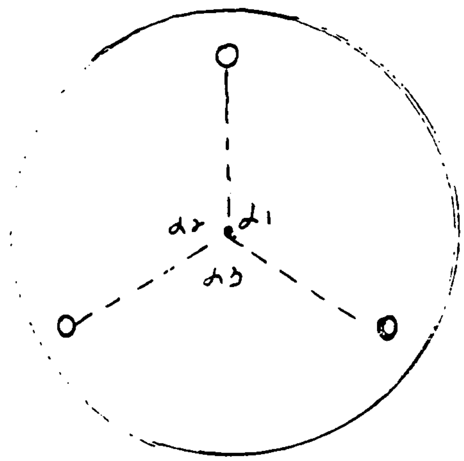


points: (in mm)
(17.120, 20.540)
(20.150, 23.700)
(24.002, 18.000)

Considering the tolerances on these readings, approximate the maximum possible area of the hole and the minimum possible area of the hole. Include a copy of your MathCad notebook and a brief paragraph summarizing your work.

PROBLEM 4

A company produces circular metal plates. Three holes are drilled into the plate as shown.



R = radius of plate

r = radius of hole

d = distance from center of hole to center of plate

If the plate is produced "perfectly", R = 120 mm, r = 20 mm, d = 95 mm, α_i = 120°.

The following readings are taken from various points on the plate. The origin is at the center of the plate.

	coordinates of points in mm
edge of plate	(89.502, 79.934) (-12.612, 119.335) (15.782, -118.958)
hole 1	(10.200, 112.204) (-5.611, 114.197) (1.510, 114.943)
hole 2	(-65.010, -37.396) (-100.215, -38.608) (-80.452, 27.583)
hole 3	(71.249, -53.545) (104.328, -31.920) (80.456, -59.336)

Given the above data, discuss the quality of the production of this plate. Include mathematical evidence to support your opinion. (You can ignore the error in the coordinates.)

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PROBLEM 5

When an engineer investigates a problem he or she may know just enough information to solve the problem. However, frequently not enough information is available or too much information is known. Given below is information about several circular holes. For each hole:

a) determine if there is enough information to find an equation of the circle;

b) if there is enough information (or too much), find an equation;

c) if insufficient information is given, state the minimal amount of additional information needed to find an equation.

Where you can find an equation, do so in the most efficient way. Use technology only if you can't find the equation quickly "by hand".

1. r = 32.400 mm
   center: (15.210, -16.213)
   (in mm)

2. r = 16.000 mm
   2 points on circle (in mm):
   (0.001, 5.001)(32.001, 5.001)

3. center (in mm): (3.210, 6.215)
one point on circle: (8.213, 16.318)
(in mm)

4. two points on circle (in mm):
(16.821, -2.314) (25.618, 8.921)

5. r = 25.00 mm
one point on circle (in mm)
(22.812, 16.218)

6. center (in mm): (16.231, 25.218)
two points on circle (in mm):
(16.231, 35.218) (26.231, 25.218)

7. 4 points on circle (in mm):
(3.000, 2.646)
(3.464, 2.000)
(1.000, -3.873)
(-3.122, 2.500)

APPENDIX D

Sample Real Life Problem
With Simplified Lead-in

DISTANCE, RATE, TIME PROBLEMS

In this activity you will study problems involving distance, rate and time. A distance is a measure of length and is measured in linear units such as miles, feet, inches, kilometers, meters, centimeters, etc. Time is usually measured in hours, minutes or seconds. The rate in these problems is speed and is a ratio of distance to time. The units could be miles per hour, feet per minute, inches per second or any unit of length per unit of time. The following problems gradually build in difficulty. The last two problems are similar to those solved in industry. The skills you learn in the introductory problems will be important when solving the last two problems. Your answers for all problems must include the correct units.

INTRODUCTORY PROBLEMS

1. Identify the distance, rate and time in each of the following scenarios.

   a. A woman travels 150 miles at 50 miles per hour. She completes the trip in 3 hours.

   distance = time = rate =

   b. A robot moves 400 inches in 2 minutes.

   distance = time = rate =

   c. A man runs 12 miles at 6 miles per hour.

   distance = time = rate =

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2. Proportions can be helpful when solving distance, rate, time problems. Use your knowledge of proportions to solve the following.

a. $\frac{165 \text{ miles}}{3 \text{ hours}} = \frac{x}{5 \text{ hours}}$

b. A bicyclist travels at 15 miles per hour. How long does it take her to travel 25 miles?

c. Write a problem that could be solved with the ratio in part a.

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3. Frequently "real life" distance, rate, time problems involve more than one rate and/or dwell times. During a dwell time the distance traveled is zero. For example, if you are driving and stop at a stop sign for 15 seconds, you dwell for 15 seconds. Write a detailed plan for solving each of the following problems and then solve.

a. Jason lives in the country, 32 miles from the nearest grocery store. When he realizes he has nothing to cook for dinner he drives to this store. He begins by traveling 25 miles on the freeway at 50 miles per hour. The remainder of the trip is on surface roads traveling the posted limit of 35 miles per hour. He spends 15 minutes in the store and then returns home along the same route at the same speeds. How long does the total trip take?

b. Jason is out of food again. It is 5:00 pm. His date will arrive for dinner at 7:00 pm. It will take him 40 minutes to prepare the dinner. Assuming he takes the same route as described in part a, will not speed on the surface roads and plans to spend 15 minutes in the store, how fast must he drive on the freeway so he can have dinner prepared by 7:00 pm?

c. The legal limit on the freeway is 65 miles per hour and the police use this stretch of highway to "make their ticket quota." Therefore, the solution in part b could be costly for Jason. If Jason will abide by both speed limits, how can he still have dinner prepared by 7:00 pm? Be specific.

MACHINING EXAMPLE

During an assembly process, a hole must be drilled 4" deep into a part. The drill slide travels 18 total inches. The first 14 inches, the slide travels at a rate of 200 inches per minute. The last 4 inches, the slide moves at a rate of 60 inches/minute. The slide dwells for 1 second at the end of the stroke to clear any chips. The slide returns at the same rates as it advanced.

a) What is the cycle time of this machining process?

b) What would the rapid feed rate need to be to obtain a cycle time of 16 seconds for this process?

Robots can be programmed to carry out various transformations. At Ford Motor Co. Lima Engine Plant, a robot uses translations to put valves into a cylinder head. The cylinder head moves down the assembly line and stops in front of the robot. The arm of the robot moves out a distance of 18" to pick up the valves. The arm dwells for 1 second to allow the gripper to grip the valves. The robot arm then moves up a distance of 6" over a distance of 8", and down a distance of 8" into a basin of oil. The robot arm dwells 1 second in the oil to coat the valves. The robot moves up to it's previous height. The robot moves over 10" to a point just above the cylinder head. The robot moves down 9" and inserts the cylinder head. The robot dwells 1 second to allow the valves to clear the gripper and then moves up 9" to end the cycle. All movements are either horizontal or vertical.

a) If the robot can move at a speed of 200 in/min, how long must the assembly line stop to allow the process to be completed?

b) In order to be more cost effective, the plant only wants the line to stop for 18 seconds. How fast must the robot move to complete the job in this amount of time?

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