An analysis of student achievement and attitudes by gender in computer-integrated and non-computer-integrated first year college mainstream calculus courses.

Mary Ann Corbo Connors
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AN ANALYSIS OF STUDENT ACHIEVEMENT AND ATTITUDES
BY GENDER IN
COMPUTER-INTEGRATED AND NON-COMPUTER-INTEGRATED FIRST
YEAR COLLEGE MAINSTREAM CALCULUS COURSES

A Dissertation Presented
by
MARY ANN CORBO CONNORS

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of
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School of Education
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DEDICATION

To
my husband, Ed,
my son, Jim,
my daughter, Kathleen
and
my parents,
Dominick and Josephine Corbo
ACKNOWLEDGEMENTS

I am deeply indebted to the following people whom I wish to thank:

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Dr. Edward A. Connors for his inspiration, support and love.
ABSTRACT

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FEBRUARY 1995

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Directed by: Professor William J. Masalski

This study investigates relationships between gender and achievement as well as gender and attitudes in a computer-integrated first year college mainstream calculus course in comparison with a similar non-computer-integrated course. The investigator analyzed data from pilot and experimental studies conducted at the University of Connecticut at Storrs in 1989 - 1993 and 1993 - 1994, respectively, in order to compare the calculus courses with respect to student achievement and attitudes with a focus on gender. Both quantitative and qualitative methods were employed. Quantitative research instruments included common final examination scores and an attitude questionnaire; data were analyzed by ANOVA/ANCOVA and Chi-Square. Students were also interviewed to gain insights into their attitudes about their calculus course experience. The samples sizes of the
experimental and control groups, respectively, were as follows for each analysis: common final examination score, Fall 1989 (25, 19), Spring 1990 (30, 26), Fall 1993 (102, 107), Spring 1994 (46, 84); the 1989-1993 study of number of subsequent courses (for which calculus is a prerequisite) and achievement in those courses, (54, 42); the 1993 - 1994 attitude survey, (93, 70); and interviews, (21, 19).

Results of the achievement study indicated that students in the computer-integrated course performed significantly better on the common final exam in Fall 1993 and suggested that female students in the computer-integrated calculus course benefited more than any other subgroup. In the 1989 - 1993 pilot study, there was a significantly higher mean number of subsequent courses taken by male students than by female students; however, female students' mean average grades in subsequent courses were significantly higher than mean average grades of male students. The results of the attitude survey and interviews indicated that the students in the experimental group tended to use calculators and computers more often for solving problems. Furthermore, the study revealed that the majority of respondents enjoy solving mathematics problems and believe that: calculus is useful and can be applied to real world problems; there is more than one way to solve a problem; and gender does not affect a person's potential to be a scientist or an engineer. Overall, results of the investigation suggest that a computer-integrated calculus course is effective in the teaching of calculus. Recommendations and suggestions for future research are offered.
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CHAPTER I

INTRODUCTION

Background and Statement of the Problem

Modern technology has provided the means for exciting mathematical discoveries and new approaches for teaching and learning mathematics. Currently there is a nationwide effort to revitalize the teaching and learning of calculus. In the introduction of the 1988 publication, *Calculus For A New Century: A Pump, Not A Filter*, Lynn Arthur Steen apprises:

Nearly one million students study calculus each year in the United States, yet fewer than 25% of these students survive to enter the science and engineering pipeline. Calculus is the critical filter in this pipeline, blocking access to professional careers for the vast majority of those who enroll. . . . These facts led Robert White, President of the National Academy of Engineering, to suggest that calculus must become a pump rather than a filter in the nation's scientific pipeline. (p. xi)

Further, in "Mathematics for All Americans" Steen (1991) points out:

"Losses from the mathematics 'pipeline' come disproportionately from females" (p. 132).

Immense interest in the need for calculus reform and its great importance drew over six hundred mathematicians, scientists and educators to participate in a national colloquium, *Calculus For A New Century* sponsored by the National Academy of Sciences and the National Academy of
Engineering in Washington, D.C. on October 28-29, 1987. The publication, *Calculus For A New Century: A Pump, Not A Filter*, contains the plenary and panel addresses, responses solicited from representatives of the concerned constituencies, reports gathered from the conference working groups, background papers on issues for the conference, a selection of examination questions from various types of schools, position papers important to calculus reform from other sources, and a list of participant names and addresses to facilitate future exchanges of ideas. *Calculus For A New Century: A Pump, Not A Filter* together with the 1986 publication *Toward a Lean and Lively Calculus* provides illustrations of efforts to reform the teaching of calculus.

At the Mathematicians and Educational Reform Network (MER) Workshop on Calculus Reform at Ann Arbor Michigan July 29 - August 1, 1993 and the Videoconference entitled *Meeting The Challenge: Calculus Renewal* sponsored by the National Science Foundation October 13, 1993, leaders in the calculus reform movement reported that there is a strong indication that appropriate use of computer software enhances the teaching and learning of calculus. However, a small percentage of calculus instructors use it. According to Richard D. Anderson and Donald O. Loftsgaarden in "A Special Calculus Survey: Preliminary Report" conducted in 1987 by the Mathematical Association of America (MAA) and the Mathematical Sciences Education Board (MSEB): "About 3% of all calculus students have some computer use required in homework assignments" (p. 216).
More research is needed to assess such computer-integrated calculus courses. Benard Hodgson's (1988) response to the Calculus for a New Century Colloquium ended:

A lot of people in different places are now getting their feet wet in trying new approaches to calculus teaching. . . . We are now in a phase where experiments need to be performed, evaluated, and communicated to others. . . . only such efforts can produce, as was wished by Robert M. White in his keynote address, a calculus that is no longer a filter but a pump in the scientific pipeline. (p. 50)

**Purpose and Objectives of the Study**

The purpose of this study is to find, analyze and disseminate information pertaining to relationships between gender and achievement and gender and attitudes in a computer-integrated first year college mainstream calculus course in comparison with a similar non-computer-integrated course. The investigator analyzed data from a 1989 - 1993 National Science Foundation funded pilot study and a 1993 - 1994 experimental study conducted at the University of Connecticut at Storrs in order to compare a computer-integrated calculus course and a non-computer-integrated calculus course with respect to student achievement and attitudes with a particular focus on gender. Both quantitative and qualitative methods were employed. Instruments for the quantitative research include the common final examination scores and the attitude questionnaire. The statistical analysis method of the quantitative data is ANOVA/ANCOVA and Chi-Square. For the qualitative research, the
investigator interviewed students to gain insight into their attitudes about their calculus course specifically and mathematics education more generally. The dissertation research investigates, with a particular focus on gender:

* how student achievement in a computer-integrated calculus course compares with that in a non-computer-integrated calculus course in the 1989 - 1993 pilot study and the 1993 - 1994 experimental study;
* how attitudes of students in a computer-integrated calculus course compare with those of students in a non-computer-integrated calculus course in the 1993 - 1994 experimental study;
* how enrollment in subsequent courses for which calculus is a direct prerequisite compares between students in a computer-integrated calculus course and students in a non-computer-integrated calculus course in the 1989 - 1993 pilot study; and
* how performance in subsequent courses for which calculus is a direct prerequisite compares between students in a computer-integrated calculus course and students in a non-computer-integrated calculus course in the 1989 - 1993 pilot study.

**Rationale**

It is important for the mathematical community to make progress in improving calculus teaching and learning for all students, particularly women. The dissemination of calculus reform information is underway via literature,
electronic mail, workshops, conferences and videoconferences. For example, four NSF funded calculus curriculum projects designed to increase student success rate and/or improve instruction were discussed with viewers calling in questions in a Calculus Renewal Videoconference October 13, 1993: The Harvard University Core Calculus Consortium, the Oregon State University Laboratory Calculus Course, the New Mexico State University From Projects to Themes: The Evolution of Calculus Classes, and Duke University Project CALC: Calculus as a Laboratory Course. Mathematicians and Educational Reform Network (MER) Workshops and Newsletters on Calculus Reform provide valuable information and resources. The Calculus in Context Project in the Five College Consortium in Western Massachusetts Conference facilitated communication between instructors who were interested in implementing innovative methods and those who shared their experiences after experimentation. As an instructor of a computer-integrated calculus course using Mathematica for classroom demonstrations and student experiments in computer labs one period per week, this author is interested in researching the effectiveness of such computer-integrated calculus courses. Further, it is hoped that sharing the results of this research with other instructors and administrators will contribute to the successful teaching and learning of calculus and make it more accessible to faculty and students than the current status quo. Many educators are reluctant to incorporate the use of computers in the teaching of calculus. Lynn Arthur Steen (1987) explains:
... many mathematicians believe that computers are rarely appropriate for mathematics instruction; theirs is a world of mental insight and abstract constructions, not of mechanical calculation or concrete representation. Most mathematicians, after all, choose mathematics at least in part because it depends only on the power of mind rather than on a variety of computational contrivances. (p. 231)

In order to effect change, instructors and administrators need information about student achievement and attitudes in computer-integrated and traditional calculus.

Definition of Terms

ANOVA: Analysis of Variance uses an $F$ statistic and its P-value (probability) to evaluate the null hypothesis that all of several population means are equal.

ANCOVA: Analysis of Covariance statistically adjusts variables to increase the precision of an experiment.

Black box computer program: A program with code that is hidden from the user.

Chi-Square. The chi-square statistic is a measure of how much of the observed cell counts in a two-way table diverge from the expected cell counts.

Computer program code: Instructions written in computer language.
Mainstream Calculus Courses (Main-Track Calculus): The sequence of calculus courses for science and engineering majors as opposed to the applied calculus sequence for business majors or the honors calculus sequence.

Scope and Delimitations

In the 1989 - 1993 pilot study the experimental group was comprised of randomly assigned first year mainstream calculus students in two small computer - integrated classes. One experimental group was taught by Professor Hurley and the other by a male graduate teaching assistant. In the 1993 - 1994 study the experimental group was comprised of first year mainstream calculus students in computer-integrated classes. The students in the computer-integrated calculus classes were not assigned at random; students selected the computer-integrated calculus course. The fall semester 1993 experimental classes (Math 115 V) were instructed by Professor Hurley, another male professor and two female graduate teaching assistants. The spring semester 1994 experimental classes (Math 116 V) were instructed by Professor Hurley and two graduate teaching assistants (one male and one female). One of the four lecture periods each week was replaced by a computer lab period for the experimental group. The computer lab contained 27 Macintosh Se-30's, 3 Macintosh II's, 3 Image Writer II's and a LaserJet III printer. According to Professor Hurley, a unique feature of the University of
Connecticut project is the examination of the code of locally written True BASIC 4.0 (Kemeny - Kurtz, 1993) numerical and graphical programs. Approximately 10% of the computer laboratories work involved the symbolic-computation application, Theorist. Other software used was True Basic 3D Graphics Library, 3D Analyzer, and True BASIC Calculus (Hurley, 1993).

In the 1989 - 1993 pilot study the control group comprised of randomly assigned first year mainstream calculus students in a traditional class with no computer augmented materials and four lectures per week. The class was taught by a male graduate teaching assistant. In 1993 - 1994 the control group comprised of first year mainstream calculus students in traditional classes with no computer augmented materials and four lectures per week. The students in the non-computer-integrated calculus classes were not assigned at random; students selected the non-computer-integrated calculus course. The control classes (Math 115 Q and Math 116 Q) were instructed by a male professor and three male graduate teaching assistants fall semester 1993 and a male professor and two male graduate teaching assistants spring semester 1994.

Calculus students in both experimental and control groups used the same course outline including the same homework problems which emphasized conceptual mastery as well as connections with other fields. Both groups used the same text: Calculus by James Hurley in 1989 - 1990 and Calculus: A Contemporary Approach by James Hurley in 1993 - 1994. Common final exams (@ 200 points each) were made jointly by all faculty teaching either type of calculus course and were administered to students in
both experimental and control groups. The final exam in Fall 1989 and Fall 1993 were concept focused; whereas the final exam in Spring 1990 was almost entirely computational and the Spring 1994 final exam was somewhat conceptual but primarily computational. Computers were not used for the common final exams.

Calculus students in both experimental and control groups in the 1989 - 1993 pilot study were randomly assigned; however, there was some adding and dropping of students during the "add/drop" period as usual.

The quantitative results of this research are subject to the limitations of the manner in which the courses were conducted, the way in which instructors and students were selected, the kind of research design, the instruments and the methods of analysis. The results of the qualitative analysis are delimited by the number of students and instructors willing and/or able to participate in the interview. Limiting factors include weather, reliability of interviewing hardware (tapes, tape recorders, telephone, e-mail), time of day and/or time of semester schedule (beginning, mid-term, end).
CHAPTER II
LITERATURE REVIEW

The Call for Reform in Calculus Instruction

Calculus courses are a sieve for many Americans who wish to pursue majors in computer science, engineering, mathematics, science, or statistics - disciplines for which calculus is a direct prerequisite. Some educators believe that a critical situation exists which threatens the nation's supply of scientists and engineers and its capacity to compete in international economic enterprises. "There is a crisis today in mathematics and science education," said Thomas W. Tucker, professor of mathematics at Colgate University. "Like it or not, calculus is the linchpin of that structure." (McDonald, 1987, p. A1)

Half of the college students who enroll in mainstream calculus withdraw or fail the course (Anderson & Loftsgaarden, 1987, p.215). As reported by Kim McDonald (1987):

What's more, those who successfully complete calculus frequently fail to understand the basic concepts of calculus or appreciate its importance, because it is taught in a bland and unimaginative manner, using . . . rote "plug and chug" exercises that have little connection with problems in the real world. (p. A1)

At a two-day (October 28-29, 1987) meeting at the National Academy of Sciences, Calculus for a New Century, more than 600 educators agreed that a national effort was necessary to bring calculus into the computer age. Even some mathematicians who did not believe there is a crisis in calculus conceded
that student use of computers can improve the current state of calculus. (Peterson, 1987, p. 317).

Experiments incorporating computer-integrated calculus courses to enhance the teaching and learning of calculus are underway at various colleges and universities in the United States. A partial list includes: Dartmouth, Duke, Harvard, Oregon State, and New Mexico State Universities, the University of Connecticut at Storrs, the University of Illinois, the University of Massachusetts Amherst, and others. Leaders in the reform movement report that there is evidence that computer-integrated calculus courses enhance the teaching and learning of calculus. For example, Kyungmee Park (1993) describes a comparative study of the traditional calculus course vs. the Calculus & Mathematica course conducted at the University of Illinois. On the basis of his quantitative and qualitative analysis, he accounted:

The result of the achievement test was that the C&M group, without seriously losing computational proficiency, was much better at conceptual understanding than was the traditional group. . . . The attitude survey results indicated that the C&M's group's disposition toward mathematics and computer was far more positive than that of the traditional group. (p. 119 - A)

Studies Supporting the Effectiveness of Computer-Enhanced Calculus

In her qualitative study of interactions, concept development and problem-solving in a calculus class immersed in the computer algebra system Mathematica, Deborah Crocker (1991/1992) reported:

This study documents improvement in the understanding of the concept of derivative by the middle of the second quarter of calculus. All participants developed a strong connection between the concept of derivative and slope. (p. 2850-A)

In his dissertation on the effects on achievement of using True BASIC software capable of symbolic manipulation to reduce hand-generated symbolic manipulation (Calculus by John Kemeny) in freshman calculus, Robert Cunningham (1991) concluded:

This study suggests that the use of the software improved achievement and did not cause damaging effects when access was denied. However, success required instructor use in the classroom in tandem with extensive student use both outside of the classroom and on tests. (p. 2448-A)

John Siler's experiment at the University of Miami involved replacing one of the four weekly Calculus I lecture hours with a two-hour mandatory lab period in the experimental section. True BASIC Calculus and Calculus Toolkit were the software packages used to design the lessons which could be adapted for use with another software package by rewriting the instructions. Siler (1990) reported in his dissertation abstract:

Student response to the labs, as reflected in written evaluations and in the level of interest observed by the author, was generally positive. Roughly three-quarters of the students preferred the lab to an
additional hour of lecture, and the same number felt the lab was more beneficial than the additional lecture hour would have been. Furthermore, the students' grasp of fundamental concepts was generally stronger than that of other similar groups with which the author has worked. The visual representation of mathematical ideas was the primary advantage of the lab. Other advantages included the emphasis on a more direct intuitive comprehension of the material, the promotion of active involvement in the learning process, the opportunity for student collaboration, which was encouraged but not required, and the cultivation of careful observation and a high level of engagement with the material. (p. 3007-A)

Fredric Tufte discussed two experiments in which students enrolled in an engineering calculus sequence in the experimental group were required to write computer programs to evaluate limits, find derivatives and approximate Riemann integrals. In one experiment 20 students met for an additional period each week for one semester, during which time they were given supplemental instruction. In a second experiment 32 students used the supplemental materials with no additional time allotted for supplemental instruction. Control subjects in other calculus classes were paired with experimental subjects on the basis of pretest scores and other factors. It was determined that the experimental groups performed significantly better than did the control groups. In the second experiment the experimental group performed no worse than other calculus classes on the common final examination. According to Tufte (1990):

Analysis of subtest results indicated that experimental subjects were better able to recognize various forms of the definitions of the derivative and integral, and to relate those forms as well as algebraic representations of functions to the graphical representations of the functions. Experimental subjects developed a geometric perspective of derivatives and integrals that was lacking in control subjects. (p.1149-A)
Studies Contradicting the Effectiveness of Computer-Enhanced Calculus

Juan Melin-Conejeros investigated the effects of doing calculus homework assignments in a mathematics laboratory equipped with the Computer Algebra System, Derive, on students' achievement and attitude towards mathematics. Derive was not used for class instruction. The 12 students in the experimental class were assigned homework which was to be done in the computer laboratory with Derive. The 16 control group students completed the same type of homework without the computer.

Melin-Conejeros (1993) reported the following results and recommendations:

1. There were no differences between treatment groups on overall achievement, on skills achievement or on concept achievement.
2. There was no difference between the attitude of the two treatment groups, although, overall the attitude of both groups decreased during the semester.
3. The interviews revealed that students who had used Derive for their homework had a better understanding of selected concepts: increasing and decreasing functions, asymptotes, concavity of graphs of function, limits of functions, and continuity.

As a result of the study and prior research, it is recommended that if a computer algebra system is to be used in teaching calculus, it should not be used for homework only. It should be integrated with all instruction both in and out of class. Further, homework exercises should be designed to specifically take advantage of the capabilities of the computer algebra system. (p. 2283-A)

In Don Hamm's 1989 study, a computer-oriented calculus instructional program using microcomputer software for in-class presentations and homework assignments were developed, implemented, and evaluated. Hamm concluded that "the use of the microcomputer in introductory calculus
instruction does not significantly effect [sic] either student achievement in calculus or student attitude toward mathematics." (p. 2817-A)

Sutep Thongyoo conducted an experiment at Syracuse University to determine if the use of microcomputer software (The Calculus Toolkit) would increase the achievement of calculus students. He reported in 1989:

The results of the study showed no significant difference between the achievement of students taught by using microcomputer software and those taught by the traditional method. Some factors that might have affected these findings, such as: the nature of the assignments, class time, location of the microcomputers, and the software, were discussed. (p. 1588-A)

Although no significant differences were found between computer-integrated and non computer-integrated calculus courses with respect to student achievement and attitude, factors that may have affected the results include:

1. design of homework exercises and use of the computer software solely for homework outside of class (Melin-Conejeros, 1993),
2. the nature of the assignments, class time, location of the microcomputers, and the software (Thongyoo, 1989).

Studies Including Information on Success of Women in Calculus

Statistics show that a disproportionate number of losses in the mathematics "pipeline" come from women. The National Science Foundation 1992 report, Women and Minorities in Science and Engineering: An Update,
reveals that a major factor contributing to women's underrepresentation in the science and engineering work force is that, at any educational level, women do not participate in science and mathematics training to the same extent as do men. Data and assessments indicate that leakages in the science and engineering education pipeline are greater for females than for men (p. 15).

Yet, according to Alice McKee (1992) in the foreword of the American Association of University Women's How Schools Shortchange Girls:

By the turn of the century, two out of three new entrants into the workforce will be women and minorities. This work force will have fewer and fewer decently paid openings for the unskilled. It will require strength in science, mathematics and technology - subjects girls are still being told are not suitable for them. (p. v.)

Barbara Rives examined selected affective and cognitive variables related to student success in college mathematics, especially calculus, college algebra and developmental mathematics. Rives (1992) recounted:

The exogenous variables of gender and locus of control, and the endogenous variables of mathematics preparation, mathematics attitude, and length of time since the student's last mathematics course were posited to have direct and indirect relations to student success in mathematics. . . . The findings of the project indicated women had significantly less mathematics preparation, less positive mathematics attitude, and more time since their last mathematics course; however, when all other factors were equal, they tended to be more successful in the course. (p. 3134-A)

In a study to measure the effect of two multiple embodiment instructional sequences on the topic of volume of rectangular solids on student achievement, Ruth Johnson investigated (1) the sequence with computer, (2) the same sequence without computer, and a textbook-based sequence. Johnson's (1989) results revealed:
Males outperformed females on knowledge and comprehension questions; females outperformed males on the computer sequence; and on both tests, males and females demonstrated equal achievement on application and analysis and total test scores. Two trends were noted: (1) students in the embodiment sequence without computer produced higher scores post-instruction, but students in the computer embodiment sequence scored higher post-retention, and (2) low ability students in the computer sequence scored lower than their counterparts in the other sequences. (p. 2370-A)

Concerning instruction of volume of rectangular solids, Johnson recommended that use of the computer should be considered in embodiment instruction and assumption that male achievement is superior to female achievement in this area should not be made.

Earlier Investigations

Experiments involving computer-extended college calculus courses in the late 1960's and early 1970's generally required that students write computer programs to solve homework exercises or use prepared computer programs provided for them or Computer Assisted Instruction (CAI). The results of Frederick Bell's study supported the hypothesis that a computer-oriented approach to calculus is an effective method to promote understanding of concepts and to increase students' interest in calculus and does not interfere with students' learning to apply techniques of calculus (Bell, 1970, p. 1096-A).

Gary Bitter (1970/1971) investigated the effect of computer applications on achievement in a college introductory calculus course. The students in the
computer extended classes at each of three participating colleges were required to write their own computer programs in BASIC programming language to solve the specifically selected homework exercises using the computer via timesharing remote terminals. Both the control and computer extended classes at each school had the same instructor and covered the same calculus content. Bitter drew the following conclusions on the basis of the analysis of covariance:

(1) Disregarding the sex classification, the subjects which were provided with computer extended instruction achieved higher in the college introductory differential calculus course than those subjects who did not have computer extended instruction.

(2) Disregarding treatment effect, the female students achieved higher in the college introductory calculus course than the male students.

(3) The treatment effect (computer applications) was demonstrated to be equal for the sexes. (p. 6109-B)


Delmer De Boer reported that a computer-oriented approach to teaching calculus had little effect on freshman engineering students' achievement and attitudes toward mathematics, but that the fringe benefits of becoming more familiar with programming and algorithmic processes should be valuable for engineering students (De Boer, 1973/1974, p. 3912-B). Gabriel Basil concluded students can complete a course in elementary calculus, while simultaneously learning a computer language with no significant effects on their achievement.
and attitudes associated with calculus (Basil, 1974, p. 2114-A).

In her 1974 analysis of computer utilization in calculus textual materials, Linda Moulton revealed that less than one-third of U. S. universities surveyed had even one section of calculus in which the computer was being used. She commented:

It is not unusual, however, to find a delay of a decade or more between the advent of an idea and the appearance of a definitive, recognizable change in curriculum and instruction. (p. 2891-B)

Other information obtained from the questionnaires categorized the advantages of the utilization of computers in first-year calculus in terms of influence on thinking, utilitarian value, relevancy and instructional value and enumerated disadvantages involving time, cost, focus, level of difficulty and textual materials (p. 2891-B).

Related Studies

In her 1990 investigation of the effectiveness of the use of computers and graphing calculators in applied calculus, Karen Estes found (1) that students believed that the calculator and computer technologies were helpful in their learning if the student understood how to use the technology and (2) that the calculator and computer technologies positively impacted conceptual achievement (Estes, 1990, p1147-A). Phoebe Judson's experiment using the computer algebra system, Maple, in elementary business calculus convinced her that computer algebra can be used successfully in college mathematics.
instruction (Judson, 1990, p. 153). M. Kathleen Heid (1988) described three major functions of the computers in her experimental study in resequencing skills and concepts in applied calculus:

1. Computers decreased the time and attention usually directed toward mastery of computational skills.

2. Computers provided concrete data for the discussion of calculus ideas. They were used to provide data that students could examine in their search for patterns, to generate initial representations on which students could base their reasoning and to display examples and counterexamples with which students could corroborate or disprove their conjectures.

3. Computers lent flexibility to the analysis of the problem situation. Their easy display of concepts in a large range of representations made feasible the consideration of more difficult problems, opened avenues for exploring several methods of solution for a single problem, and created an environment amenable to convenient exploration of changing parameters. (pp. 10-11)

She concluded, "Students from the experimental classes spoke about the concepts of calculus in more detail, with greater clarity, and with more flexibility than did students of the comparison group" (p. 21).

Elizabeth Teles (1992) discussed results reported in the literature from studies conducted from 1958 to 1986 on use of the computer in the teaching of calculus. She concluded:

In summary, these studies show that when the computer was used to enhance calculus instruction there was small, positive, but not significant effect size. When tasks are separated for analysis, significant difference [sic] emerge for more conceptual tasks with little or no loss in manipulative skills. (p. 228)
John Rochowicz (1993) reported that a Computing Technology Utilization /Impact Questionnaire was mailed to the participants of the Calculus for a New Century Colloquium. A response rate of 65% was achieved. Findings on the extent of technology use in the calculus classroom of the survey respondents included:

1. 57% used graphing software to some degree of frequency;
2. 39% used computer algebra systems to some degree of frequency; and
3. 89% never used word processors or programming languages.

ANOVA tests revealed significant mean differences in the levels of technology use and the calculus instructor's perceptions of the impact of this use on specific topics of calculus, motivation, learning, and the role of the teacher (p. 4290-A).

More research is needed to assess such computer-integrated calculus courses. Bernard Hodgson's (1988) response to the Calculus for a New Century Colloquium ended with the following paragraph:

A lot of people in different places are now getting their feet wet in trying new approaches to calculus teaching. Attendance to this Colloquium indicates that this corresponds to a real need. We are now in a phase where experiments need to be performed, evaluated, and communicated to others. Identification of new curricula and production of related materials is a difficult and unrewarding task. But only such efforts can produce, as was wished by Robert M. White in his keynote address, a calculus that is no longer a filter but a pump in the scientific pipeline. (p. 50)
The integration of computing into mainstream calculus at the University of Connecticut at Storrs is an example of such an experiment. A distinctive feature of the project is the examination of the code of numerical and graphical programs written in True BASIC programming language with relatively little application of the symbolic computation package, Theorist (approximately 10% of the weekly computer lab period). The symbolic manipulation methods are implemented for the most part by hand and supported by numerical and graphical computer programs which illuminate the symbolic procedures as well as their conceptual foundation.

In a grant proposal submitted in 1991 to the National Science Foundation for expansion of the pilot experiment, James Hurley, the Principal Investigator, contended:

Students who learn calculus in traditional courses usually have a problem conceptualizing the definite integral. . . . But those whose initial experience in evaluating definite integrals is with code like the following, . . . really think of integrals as limits of sums. (p. 9)

He cited several benefits of students direct experience with program code to learn about definite integrals including:

1. Numerical programs such as illustrated in the example (Appendix C) build intuition about the underlying mathematical process in a way that no classroom or textual explanation can.

2. No "black-box" program is running in the background.

3. It permits active involvement of the students in the teaching/discovery process (pp. 9,10).
CHAPTER III

METHODOLOGY

The purpose of this study is to compare a computer-integrated calculus course and a non-computer-integrated calculus course with respect to male and female student achievement and attitudes in order to determine whether a computer-integrated calculus course will serve as a "pump not a filter."

An experimental pilot study funded by a National Science Foundation Grant was conducted at the University of Connecticut at Storrs to analyze the performance of students taking computer integrated calculus compared to those in traditional calculus courses and to determine if there were differences in numbers of students who took subsequent courses and their achievement in those courses for which calculus was a required prerequisite. The Principal Investigator, Professor James Hurley (1994), published results on comparison of achievement on the common final exams administered at Storrs fall semester 1989 and spring semester 1990 from the 1989-1993 pilot experiment which show that there was a difference in achievement on the common final examination favoring the computer-integrated calculus students. He apprises:

... on concept-focused common final exams since Fall, 1989, mean scores in the computer-integrated sections to which students were randomly assigned have been about half a standard deviation higher.
The Spring, 1990, final stressed hand computation, to test whether improved conceptual mastery of the material might be offset by a decline in the capacity to carry out hand symbolic computation. The experimental sections still did better -- by a smaller margin... (p. 782)

Half a standard deviation was the equivalent of one letter grade (Hurley, 1993). The common final exams (@ 200 points each) were made jointly by all faculty teaching either type of calculus course. Students in every calculus course at the University of Connecticut were included in the analysis. Class sizes varied from small classes of up to 31 students to large lecture sections of up to 119 students. The project received additional funding for expansion in 1992.

This author made arrangements with Professor Hurley to obtain the raw data necessary for her research with the understanding that she would use the raw data from the University of Connecticut study to extend the focus of the investigation of the 1989 - 1993 pilot study to the performances of subgroups based on gender. The data included information about students in small classes only at the main branch at Storrs. In addition, the investigator collected and analyzed data on students in all mainstream calculus classes (sizes were less than 40 each) at the main branch with respect to:

1. male and female student achievement for the 1993 - 1994 study and
2. student attitudes via a questionnaire administered to both experimental and control classes at the end of fall semester 1993 and student interviews which the researcher taped via audio cassette when she made site visits during spring semester 1994.
Treatment

Experimental Group

In the 1989 - 1993 pilot study the experimental group was comprised of randomly assigned first year mainstream calculus students in two small computer - integrated classes. One experimental group was taught by Professor Hurley and the other by a male graduate teaching assistant.

In the 1993 - 1994 study the experimental group was comprised of first year mainstream calculus students in computer-integrated classes. The students in the computer-integrated calculus classes were not assigned at random; students selected the computer-integrated calculus course. The fall semester 1993 experimental classes (Math 115 V) were instructed by Professor Hurley, another male professor and two female graduate teaching assistants. The spring semester 1994 experimental classes (Math 116 V) were instructed by Professor Hurley and two graduate teaching assistants (one male and one female).

One of the four lecture periods each week was replaced by a computer lab period for the experimental group. Each student was assigned to a small group (3 to 8 students) for weekly labs and homework sessions monitored by an undergraduate assistant. The computer lab contained 27 Macintosh Se-30's, 3 Macintosh II's, 3 Image Writer II's and a LaserJet III printer. According to Professor Hurley (1993), a unique feature of the University of Connecticut
project is the examination of the code of locally written *True BASIC* 4.0 (Kemeny - Kurtz, 1993) numerical and graphical programs. He explained:

Their simple code can provide helpful concrete illustrations of important underlying mathematical concepts by showing how the computer works with them at their most basic level. Their systematic logical instructions resemble the logic of proofs, and illustrate the essence of important algorithms. (p. 1)

Approximately 10% of the computer laboratories work involved the symbolic-computation application, *Theorist*. Other software used was *True Basic 3D Graphics Library*, *3D Analyzer*, and *True BASIC Calculus* (Hurley, 1993).

**Control Group**

In the 1989 - 1993 pilot study the control group was comprised of randomly assigned first year mainstream calculus students in a traditional class with no computer augmented materials and four lectures per week. The class was taught by a male graduate teaching assistant. In 1993 - 1994 the control group was comprised of first year mainstream calculus students in traditional classes with no computer augmented materials and four lectures per week. The students in the non-computer-integrated calculus classes were not assigned at random; students selected the non-computer-integrated calculus course. The control classes (Math 115 Q and Math 116 Q) were instructed by a male professor and three male graduate teaching assistants fall semester 1993 and a male professor and two male graduate teaching assistants spring semester 1994.
Both Groups

Calculus students in both experimental and control groups used the same course outline including the same homework problems which emphasized conceptual mastery as well as connections with other fields. Both groups used the same text: *Calculus* by James Hurley in 1989 - 1990 and *Calculus: A Contemporary Approach* by James Hurley in 1993 - 1994. Common final exams (200 point value) were made jointly by all faculty teaching either type of calculus course and were administered to students in both experimental and control groups. The final exam in Fall 1989 and Fall 1993 were concept focused; whereas the final exam in Spring 1990 was almost entirely computational and the Spring 1994 final exam was somewhat conceptual but primarily computational. Computers were not used for the common final exams.

In the 1989 - 1993 pilot study students were assigned at random; however, there was some adding and dropping of students during the "add/drop" period as usual.

Sample

In the 1989-1993 pilot study the sample size was comprised of 54 students in the experimental group and 42 students in the control group for the analyses of the number of subsequent courses for which calculus is a prerequisite and achievement in those courses. The sample sizes for the
common final exam score analysis in Fall 1989 were 25 students in the experimental group and 19 students in the control group. The sample sizes for the common final exam score analysis in Spring 1990 were 30 students in the experimental group and 26 students in the control group.

The 1993 - 1994 attitude survey analysis was comprised of 93 students in the experimental group and 70 students in the control group. In order to gain insight on the attitude survey responses, 40 students were interviewed - 21 from the computer-integrated calculus course and 19 from the non-computer integrated course. The sample sizes for the common final exam score analysis in Fall 1993 were 102 students in the experimental group and 107 students in the control group. The sample sizes for the common final exam score analysis in Spring 1994 were 46 students in the experimental group and 84 students in the control group.

Data

Raw data collected between 1989 and 1994 included:

- gender,
- SAT scores,
- common calculus final exam scores, subsequent courses taken (those for which calculus is a direct prerequisite),
- grades earned in subsequent courses (those for which calculus is a direct prerequisite),
student attitude questionnaire, and
audio cassette tapes and notes of student attitude interviews.
Professor Hurley obtained legal permission for this author to receive the data
(with names and social security numbers removed - on 3.5" IBM formatted
diskettes).

**Instruments**

Common Final Exams (@ 200 points each) made jointly by all faculty teaching
either type of calculus course (Appendix A)
An Attitude Questionnaire developed by the University of Connecticut
Institute of Social Inquiry with funding from the National Science Foundation
(Appendix B)

**Research Design**

The SAS statistical software package on the University of Massachusetts
mainframe DEC 5500 computer running ULTRIX version 4.2 was used for the
data analysis including:

1. the ANCOVA /ANCOVA analyses on the common final exam mean
   scores, mean number of subsequent courses for which calculus is a

29
prerequisite and mean average grades in subsequent courses for which calculus is a prerequisite and

2. the Frequency Percentage and Chi-Square analyses on the student attitude questionnaire data.

Null Hypotheses for 1989 - 1993 Pilot Study:

I. There is no significant difference in achievement in calculus among subgroups in the Fall 1989 - Spring 1990 pilot study:

(Independent variable: achievement measured by common final exam grade

Independent variables: gender, type (of calculus course))

A. There are no significant differences in common final exam mean scores between female students in the experimental group and female students in the control group;

1. There are no significant differences in Fall 1989 common final exam mean scores between female students in the experimental group and females in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between female students in the experimental group and females in the control group;

B. There are no significant differences in common final exam mean scores between male students in the experimental group and male students in the control group;
1. There are no significant differences in Fall 1989 common final exam mean scores between male students in the experimental group and males in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between male students in the experimental group and males in the control group;

C. There are no significant differences in common final exam mean scores between students in the experimental group and students in the control group;

1. There are no significant differences in Fall 1989 common final exam mean scores between students in the experimental group and students in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in common final exam mean scores between female students and male students;

1. There are no significant differences in Fall 1989 common final exam mean scores between female students and male students;

2. There are no significant differences in Spring 1990 common final exam mean scores between female students and male students.
II. There is no significant difference in the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by students among subgroups:

(Independent variable: mean number of subsequent courses taken
Independent variables: gender type (of calculus course))

A. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by female students in the experimental group and the mean number of subsequent courses taken by female students in the control group;

B. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by male students in the experimental group and the mean number of subsequent courses taken by male students in the control group;

C. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by students in the experimental group and the mean number of subsequent courses taken by students in the control group;

D. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by female students and the mean number of subsequent
courses taken by male students.

III. There is no significant difference in performance in subsequent courses among subgroups:

(Independent variable: grades in subsequent courses taken,
Independent variables: gender, type (of calculus course))

A. There is no significant difference in the mean average grades in subsequent courses between female students in the experimental group and female students in the control group;

B. There is no significant difference in the mean average grades in subsequent courses between male students in the experimental group and male students in the control group;

C. There is no significant difference in the mean average grades in subsequent courses between students in the experimental group and students in the control group;

D. There is no significant difference in the mean average grades in subsequent courses between female students and male students.

Null Hypotheses for Fall 1993 - Spring 1994 Study:

I. There is no significant difference in achievement in calculus among subgroups in the Fall 1993 - Spring 1994 experimental study:

(Independent variable: achievement measured by common final exam grade
Independent variables: gender, type (of calculus course))
A. There are no significant differences in common final exam mean scores between female students in the experimental group and female students in the control group;
   1. There are no significant differences in Fall 1993 common final exam mean scores between female students in the experimental group and females in the control group;
   2. There are no significant differences in Spring 1994 common final exam mean scores between female students in the experimental group and females in the control group;

B. There are no significant differences in common final exam mean scores between male students in the experimental group and male students in the control group;
   1. There are no significant differences in Fall 1993 common final exam mean scores between male students in the experimental group and males in the control group;
   2. There are no significant differences in Spring 1994 common final exam mean scores between male students in the experimental group and males in the control group;

C. There are no significant differences in common final exam mean scores between students in the experimental group and students in the control group;
1. There are no significant differences in Fall 1993 common final exam mean scores between students in the experimental group and students in the control group;

2. There are no significant differences in Spring 1994 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in common final exam mean scores between female students and male students;

1. There are no significant differences in Fall 1993 common final exam mean scores between female and male students;

2. There are no significant differences in Spring 1994 common final exam mean scores between female and male students.

II. There is no significant difference in attitudes between:

(Dependent variable: attitude,

Independent variables: gender, type (of calculus course))

A. female students in the experimental group and female students in the control group;

B. male students in the experimental group and male students in the control group;

C. students in the experimental group and students in the control group;

D. female students and male students.
The results of the 1989 - 1993 pilot study include comparisons by gender between the computer-integrated calculus students and the non-computer-integrated-calculus students with respect to mean common final examination scores (out of 200 points) in Fall 1989 and Spring 1990, mean number of subsequent courses for which calculus is a prerequisite, and mean grades achieved in subsequent courses for which calculus is a prerequisite.

Although students were selected at random, preliminary analyses were done to test for similarity of the groups with respect to ability. Analyses of variance with SAT Math and SAT Verbal as dependent variables respectively and Gender and Type (of calculus course) as independent variables resulted as follows:

**SAT Math**

**Fall 1989:** Gender is significant at the $0.0042 < 0.05$ level (Male students had higher SAT Math mean scores than female students);
Type (of calculus course) is significant at the 0.016 < 0.05 level
(Students in the computer-integrated course had higher mean scores than students in the non-computer-integrated course;
The interaction Gender x Type is not significant;
Spring 1990: no significant differences in Gender, Type or the interaction Gender x Type.

SAT Verbal

Fall 1989: no significant differences in Gender, Type or the interaction Gender x Type.

Spring 1990: no significant differences in Gender, Type or the interaction Gender x Type.

Null Hypotheses

I. There is no significant difference in achievement in calculus among subgroups in the Fall 1989 - Spring 1990 pilot study calculus classes:

A. There are no significant differences in common final exam mean scores between female students in the experimental group and female students in the control group;

1. There are no significant differences in Fall 1989 common final exam mean scores between female students in the
experimental group and female students in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between female students in the experimental group and female students in the control group;

B. There are no significant differences in common final exam mean scores between male students in the experimental group and male students in the control group;

1. There are no significant differences in Fall 1989 common final exam mean scores between male students in the experimental group and male students in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between male students in the experimental group and male students in the control group;
C. There are no significant differences in common final exam mean scores between students in the experimental group and students in the control group;

1. There are no significant differences in Fall 1989 common final exam mean scores between students in the experimental group and students in the control group;

2. There are no significant differences in Spring 1990 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in common final exam mean scores between female students and male students;

1. There are no significant differences in Fall 1989 common final exam mean scores between female students and male students;

2. There are no significant differences in Spring 1990 common final exam mean scores between female students and male students.
Figure 1. Mean Exam Scores Fall 1989

Common Final Exam Mean Scores Fall 1989

Table 1. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores, Standard Deviation (SD) and Standard Error (SE) Fall 1989

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>18</td>
<td>136.2</td>
<td>36</td>
<td>8</td>
<td>647.8</td>
<td>64</td>
<td>15</td>
<td>130.8</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>12</td>
<td>138.3</td>
<td>44</td>
<td>13</td>
<td>639.2</td>
<td>52</td>
<td>15</td>
<td>134.7</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>7</td>
<td>136.7</td>
<td>33</td>
<td>12</td>
<td>601.4</td>
<td>85</td>
<td>32</td>
<td>141.6</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>7</td>
<td>131.0</td>
<td>31</td>
<td>12</td>
<td>555.7</td>
<td>65</td>
<td>24</td>
<td>146.1</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>30</td>
<td>137.0</td>
<td>39</td>
<td>7</td>
<td>644.3</td>
<td>59</td>
<td>11</td>
<td>132.8</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>14</td>
<td>133.9</td>
<td>31</td>
<td>8</td>
<td>578.6</td>
<td>76</td>
<td>20</td>
<td>143.9</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>25</td>
<td>136.4</td>
<td>35</td>
<td>7</td>
<td>634.8</td>
<td>72</td>
<td>14</td>
<td>136.2</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>19</td>
<td>135.6</td>
<td>39</td>
<td>9</td>
<td>608.4</td>
<td>69</td>
<td>16</td>
<td>140.4</td>
</tr>
</tbody>
</table>
Method: Analysis of Covariance

Covariate: SAT Math

Dependent variable: Score (Common Final Examination Score out of a possible 200)

Independent variables: Type (Computer-Integrated or Non-Computer Integrated)
  Gender (Male or Female)

Level of significance: $\alpha = 0.05$

### ANCOVA TABLE

Common Final Exam Mean Scores Fall 1989

**Table 2. ANCOVA - Common final exam scores Fall 1989**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>SIG of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>940.381</td>
<td>940.381</td>
<td>0.76</td>
<td>0.3877</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>161.101</td>
<td>161.101</td>
<td>0.13</td>
<td>0.7196</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>0.674</td>
<td>0.674</td>
<td>0.00</td>
<td>0.9815</td>
</tr>
<tr>
<td>SAT Math</td>
<td>1</td>
<td>8373.910</td>
<td>8373.910</td>
<td>6.80</td>
<td>0.0129</td>
</tr>
<tr>
<td>Error</td>
<td>39</td>
<td>48058.880</td>
<td>1232.279</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A preliminary analysis with SAT Verbal as a covariate showed it to be non significant so it was eliminated from the final analysis.
The General Linear Model in SAS (used since there are unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* The covariate SAT Math is significant at the 0.013 < 0.05 level. There is a significant positive relationship between SAT Math Mean scores and the Fall 1989 Final Exam Mean scores.

* All other effects - Gender, Type and their interaction - are not significant at the 0.05 level.

Therefore we must accept the null hypotheses and conclude there is no significant difference in achievement in calculus among subgroups in the Fall 1989 pilot study:

A. There are no significant differences in Fall 1989 common final exam mean scores between female students in the experimental group and female students in the control group;

B. There are no significant differences in Fall 1989 common final exam mean scores between male students in the experimental group and male students in the control group;

C. There are no significant differences in Fall 1989 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in Fall 1989 common final exam mean scores between female students and male students.
Figure 2. Mean Exam Scores Spring 1990

Common Final Exam Mean Scores Spring 1990

Table 3. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores, Standard Deviation (SD) and Standard Error (SE) Spring 1990

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>19</td>
<td>128.2</td>
<td>42</td>
<td>10</td>
<td>631.1</td>
<td>86</td>
<td>20</td>
<td>128.2</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>21</td>
<td>122.3</td>
<td>30</td>
<td>7</td>
<td>635.7</td>
<td>56</td>
<td>12</td>
<td>122.3</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>11</td>
<td>112.1</td>
<td>33</td>
<td>10</td>
<td>574.5</td>
<td>98</td>
<td>30</td>
<td>112.1</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>5</td>
<td>133.8</td>
<td>39</td>
<td>17</td>
<td>624.0</td>
<td>66</td>
<td>30</td>
<td>133.8</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>40</td>
<td>125.1</td>
<td>36</td>
<td>6</td>
<td>633.5</td>
<td>71</td>
<td>11</td>
<td>125.2</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>16</td>
<td>118.9</td>
<td>35</td>
<td>9</td>
<td>590.0</td>
<td>90</td>
<td>23</td>
<td>122.9</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>30</td>
<td>122.3</td>
<td>39</td>
<td>7</td>
<td>610.3</td>
<td>93</td>
<td>17</td>
<td>120.1</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>26</td>
<td>124.5</td>
<td>31</td>
<td>6</td>
<td>633.5</td>
<td>57</td>
<td>11</td>
<td>128.1</td>
</tr>
</tbody>
</table>
Method: Analysis of Covariance

Covariate: SAT Math

Dependent variable: Score (Common Final Examination Score out of a possible 200)

Independent variables: Type (Computer-Integrated or Non-Computer Integrated)
Gender (Male or Female)

Level of significance: $\alpha = 0.05$

**ANCOVA TABLE**

Common Final Exam Mean Scores Spring 1990

Table 4. ANCOVA - Common final exam mean scores Spring 1990

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>SIG of F Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>12.831</td>
<td>12.831</td>
<td>0.36</td>
<td>0.5519</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>271.263</td>
<td>271.263</td>
<td>0.22</td>
<td>0.6413</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>1332.031</td>
<td>1332.031</td>
<td>1.08</td>
<td>0.3039</td>
</tr>
<tr>
<td>SAT Math</td>
<td>1</td>
<td>3156.648</td>
<td>3156.648</td>
<td>2.56</td>
<td>0.1160</td>
</tr>
<tr>
<td>Error</td>
<td>51</td>
<td>62972.254</td>
<td>1234.750</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The covariate SAT Verbal was not significant in a preliminary analysis of covariance and was eliminated from the final analysis.
The General Linear Model in SAS (used since there are unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* The covariate SAT Math is not significant at the 0.05 level.
* All other effects - Gender, Type and their interaction - are not significant at the 0.05 level.

Therefore we must accept the null hypotheses and conclude there is no significant difference in achievement in calculus among subgroups in the Spring 1990 pilot study:

A. There are no significant differences in Spring 1990 common final exam mean scores between female students in the experimental group and female students in the control group;

B. There are no significant differences in Spring 1990 common final exam mean scores between male students in the experimental group and male students in the control group;

C. There are no significant differences in Spring 1990 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in Spring 1990 common final exam mean scores between female students and male students.
II. There is no significant difference in the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by students among subgroups:

A. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by female students in the experimental group and the mean number of subsequent courses taken by female students in the control group;

B. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by male students in the experimental group and the mean number of subsequent courses taken by male students in the control group;

C. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by students in the experimental group and the mean number of subsequent courses taken by students in the control group;

D. There is no significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by female students and the mean number of subsequent courses taken by male students.

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Figure 3. Mean No. of Courses Completed

Mean Number of Subsequent Courses
For Which Calculus is a Prerequisite

Table 5. Mean number of subsequent courses completed

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>25</td>
<td>6.0</td>
<td>2.8</td>
<td>0.6</td>
<td>6.0</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>17</td>
<td>6.2</td>
<td>2.3</td>
<td>0.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>12</td>
<td>3.3</td>
<td>2.5</td>
<td>0.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>7</td>
<td>3.7</td>
<td>3.1</td>
<td>1.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>42</td>
<td>6.0</td>
<td>2.6</td>
<td>0.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>19</td>
<td>3.5</td>
<td>2.6</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>37</td>
<td>5.1</td>
<td>2.9</td>
<td>0.5</td>
<td>4.6</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>24</td>
<td>5.5</td>
<td>2.7</td>
<td>0.6</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Method: Analysis of Variance

Dependent variable: NCOURSEC (Number of courses completed for which calculus is a prerequisite)

Independent variables: Type (C-I or N-C-I)

Gender (Male or Female)

Level of significance: $\alpha = 0.05$

### ANOVA TABLE

Mean Number of Subsequent Courses for Which Calculus is a Prerequisite

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>SIG of F Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>79.678</td>
<td>79.678</td>
<td>11.14</td>
<td>0.0015</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>1.098</td>
<td>1.098</td>
<td>0.15</td>
<td>0.6966</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>0.083</td>
<td>0.083</td>
<td>0.01</td>
<td>0.9145</td>
</tr>
<tr>
<td>Error</td>
<td>57</td>
<td>407.526</td>
<td>7.150</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The General Linear Model in SAS (used since there are unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* Gender is significant at the 0.0015 < 0.05 level.
* Type is not significant at the 0.05 level.
* The interaction Gender x Type is not significant at the 0.05 level.
Therefore we accept hypotheses II A,B,C; reject hypothesis II D and conclude:

A. There is no significant difference between the mean number of subsequent courses (for which calculus is a prerequisite) taken by female students in the experimental group and the mean number of subsequent courses taken by female students in the control group;

B. There is no significant difference between the mean number of subsequent courses (for which calculus is a prerequisite) taken by male students in the experimental group and the mean number of subsequent courses taken by male students in the control group;

C. There is no significant difference between the mean number of subsequent courses (for which calculus is a prerequisite) taken by students in the experimental group and the mean number of subsequent courses taken by students in the control group;

D. There is a significant difference between the mean number of subsequent courses (for which calculus is a prerequisite) taken by female students and the mean number of subsequent courses taken by male students. There is a significantly higher mean number of subsequent courses (for which calculus is a prerequisite) taken by male students than by female students.
III. There is no significant difference in performance in subsequent courses among subgroups:

A. There is no significant difference in the mean average grades in subsequent courses between female students in the experimental group and female students in the control group;

B. There is no significant difference in the mean average grades in subsequent courses between male students in the experimental group and male students in the control group;

C. There is no significant difference in the mean average grades in subsequent courses between students in the experimental group and students in the control group;

D. There is no significant difference in the mean average grades in subsequent courses between female students and male students.
Figure 4. Mean Grades in Courses

Mean Average Grade in Subsequent Courses
For Which Calculus is a Prerequisite

Table 7. Mean average grades in subsequent courses

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>25</td>
<td>2.3</td>
<td>1.0</td>
<td>0.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>17</td>
<td>2.3</td>
<td>0.7</td>
<td>0.2</td>
<td>2.1</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>12</td>
<td>2.4</td>
<td>1.0</td>
<td>0.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>7</td>
<td>2.8</td>
<td>0.6</td>
<td>0.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>42</td>
<td>2.3</td>
<td>0.9</td>
<td>0.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>19</td>
<td>2.5</td>
<td>0.9</td>
<td>0.2</td>
<td>2.8</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>37</td>
<td>2.3</td>
<td>1.0</td>
<td>0.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>24</td>
<td>2.4</td>
<td>0.7</td>
<td>0.1</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Method: Analysis of Covariance

Dependent variable: AVGRADE (Average grade in subsequent courses for which Calculus is a prerequisite)

Independent variables: Type (C-I or N-C-I)
Gender (Male or Female)

Covariate: NCOURSC (Number of Courses Completed)

Level of significance: $\alpha = 0.05$

**ANCOVA Table**

Mean Average Grade in Subsequent Courses for Which Calculus is a Prerequisite

**Table 8. ANCOVA - mean average grades in subsequent courses**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>$\text{SIG of F}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>3.977</td>
<td>3.977</td>
<td>5.72</td>
<td>0.0202</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>0.309</td>
<td>0.309</td>
<td>0.44</td>
<td>0.5080</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>0.382</td>
<td>0.382</td>
<td>0.55</td>
<td>0.4618</td>
</tr>
<tr>
<td>NCOURSC</td>
<td>1</td>
<td>6.171</td>
<td>6.171</td>
<td>8.88</td>
<td>0.0043</td>
</tr>
<tr>
<td>Error</td>
<td>56</td>
<td>38.933</td>
<td>0.695</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Covariates SAT Math and SAT Verbal were not significant at the 0.05 level in preliminary analysis and were eliminated from the final analysis.
The General Linear Model in SAS (for unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* Covariate NCOURSC is significant at the 0.05 level. There is a positive relationship between the number of courses completed and the mean average grade.

* Gender is significant at the 0.020 < 0.05 level.

* Type is not significant at the 0.05 level.

* The interaction Gender x Type is not significant at the 0.05 level.

Therefore we accept hypotheses III A, B, C; reject hypothesis III D and conclude:

A. There is no significant difference in the mean average grades in subsequent courses between female students in the experimental group and female students in the control group;

B. There is no significant difference in the mean average grades in subsequent courses between male students in the experimental group and male students in the control group;

C. There is no significant difference in the mean average grades in subsequent courses between students in the experimental group and students in the control group;

D. There is a significant difference in the mean average grades in subsequent courses between female students and male students.
Because students were not selected at random, preliminary analyses were done to test for similarity of the groups with respect to ability. Analyses of variance with SAT Math and SAT Verbal as dependent variables respectively and Gender and Type (of calculus course) as independent variables resulted as follows:

SAT Math

Fall 1993: Gender is significant at the 0.01 < 0.05 level (Male students had higher SAT Math mean scores than female students);
Type (of calculus course) is not significant;
The interaction Gender x Type is significant at the 0.04 < 0.05 level;

Spring 1994: no significant differences in Gender, Type or the interaction Gender x Type.

SAT Verbal

Fall 1993: no significant differences in Gender, Type or the interaction Gender x Type.

Spring 1994: no significant differences in Gender, Type or the interaction Gender x Type.
Null Hypotheses

I. There is no significant difference in achievement in calculus among subgroups in the Fall 1993 - Spring 1994 experimental study:

A. There are no significant differences in common final exam mean scores between female students in the experimental group and female students in the control group;

1. There are no significant differences in Fall 1993 common final exam mean scores between female students in the experimental group and female students in the control group;

2. There are no significant differences in Spring 1994 common final exam mean scores between female students in the experimental group and female students in the control group;

B. There are no significant differences in common final exam mean scores between male students in the experimental group and male students in the control group;
1. There are no significant differences in Fall 1993 common final exam mean scores between male students in the experimental group and male students in the control group;

2. There are no significant differences in Spring 1994 common final exam mean scores between male students in the experimental group and male students in the control group;

C. There are no significant differences in common final exam mean scores between students in the experimental group and students in the control group;

1. There are no significant differences in Fall 1993 common final exam mean scores between students in the experimental group and students in the control group;

2. There are no significant differences in Spring 1994 common final exam mean scores between students in the experimental group and students in the control group;
D. There are no significant differences in common final exam mean scores between female students and male students;

1. There are no significant differences in Fall 1993 common final exam mean scores between female students and male students;

2. There are no significant differences in Spring 1994 common final exam mean scores between female students and male students.
Figure 5. Mean Exam Scores Fall 1993

Common Final Exam Mean Scores Fall 1993

Table 9. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores, Standard Deviation (SD) and Standard Error (SE) Fall 1993

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>70</td>
<td>122.8</td>
<td>32</td>
<td>4</td>
<td>624.5</td>
<td>77</td>
<td>9</td>
<td>120.6</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>64</td>
<td>113.2</td>
<td>39</td>
<td>5</td>
<td>600.8</td>
<td>102</td>
<td>13</td>
<td>113.9</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>32</td>
<td>122.0</td>
<td>31</td>
<td>5</td>
<td>575.7</td>
<td>55</td>
<td>10</td>
<td>127.8</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>43</td>
<td>115.2</td>
<td>39</td>
<td>6</td>
<td>595.8</td>
<td>64</td>
<td>10</td>
<td>117.6</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>134</td>
<td>118.2</td>
<td>36</td>
<td>3</td>
<td>613.2</td>
<td>91</td>
<td>8</td>
<td>117.2</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>75</td>
<td>118.1</td>
<td>36</td>
<td>4</td>
<td>587.2</td>
<td>61</td>
<td>7</td>
<td>122.7</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>102</td>
<td>122.5</td>
<td>32</td>
<td>3</td>
<td>609.2</td>
<td>75</td>
<td>7</td>
<td>124.2</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>107</td>
<td>114.0</td>
<td>39</td>
<td>4</td>
<td>598.8</td>
<td>89</td>
<td>9</td>
<td>115.7</td>
</tr>
</tbody>
</table>
The graphs in Figure 6 illustrate that the female students in the computer-integrated calculus course had a lower SAT Math mean score than the females in the non-computer-integrated course and the males in both types of courses. However Figure 7 indicates that the mean exam score of the female students in the computer-integrated calculus course is higher than the females and males in the non-computer-integrated course. In fact, the mean exam score of the female students in the computer-integrated calculus course (122.0) is almost the same as that of the males in the computer-integrated course (122.8). An ANOVA with SAT Math as a dependent variable and Gender and Type as independent variables indicated that there is a significant interaction Gender x Type at the $0.04 < 0.05$ level and that Gender is significant at the $0.01 < 0.05$ level. Male students had a higher SAT Math mean score than female students.
Method: Analysis of Covariance

Covariate: SAT Math

Dependent variable: Score (Common Final Examination Score out of a possible 200)

Independent variables: Type (Computer-Integrated or Non-Computer Integrated) Gender (Male or Female)

Level of significance: $\alpha = 0.05$

**ANCOVA TABLE**

Common Final Exam Mean Scores Fall 1993

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>SIG of F Pr $&gt;$ F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>1845.165</td>
<td>1845.165</td>
<td>1.80</td>
<td>0.1811</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>3815.995</td>
<td>3815.995</td>
<td>3.72</td>
<td>0.0550</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>134.813</td>
<td>134.813</td>
<td>0.13</td>
<td>0.7172</td>
</tr>
<tr>
<td>SAT Math</td>
<td>1</td>
<td>35241.215</td>
<td>35241.215</td>
<td>34.40</td>
<td>0.0001</td>
</tr>
<tr>
<td>SAT Math x Type</td>
<td>1</td>
<td>2914.066</td>
<td>2914.066</td>
<td>2.84</td>
<td>0.0932</td>
</tr>
<tr>
<td>SAT Math x Gen</td>
<td>1</td>
<td>2169.513</td>
<td>2169.513</td>
<td>2.12</td>
<td>0.1472</td>
</tr>
<tr>
<td>Error</td>
<td>202</td>
<td>206964.510</td>
<td>1024.577</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10. ANCOVA - mean exam scores Fall 1993
Preliminary analysis with SAT Verbal as a covariate showed it to be not significant so it was eliminated from the final analysis.

The General Linear Model in SAS (used since there are unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* The covariate SAT Math is significant at the 0.0001 level. There is a significant positive relationship between SAT Math Mean scores and the Fall 1993 Final Exam Mean scores.

* Interactions - SAT Math x Gender (0.1472) and SAT Math x Type (0.0932) were not significant at the 0.05 level.

* All other effects - Gender, Type and their interaction - are not significant at the 0.05 level;

* Type is significant at the 0.0550 level.

Therefore we must accept hypotheses I A 1, B 1, D 1; reject hypothesis I C 1, and conclude:

A 1. There are no significant differences in Fall 1993 common final exam mean scores between female students in the experimental group and female students in the control group;

B 1. There are no significant differences in Fall 1993 common final exam mean scores between male students in the experimental group and male students in the control group;
C 1. There are significant differences in Fall 1993 common final exam mean scores between students in the experimental group and students in the control group; students in the computer-integrated calculus course had a higher mean exam score than students in the non-computer-integrated calculus course.

D 1. There are no significant differences in Fall 1993 common final exam mean scores between female students and male students.

However, it is important to note here that when the ANCOVA is done without gender as a factor, type of calculus course is a significant factor. There are differences in the Fall 1993 common final exam mean scores significant at the $0.0343 < 0.05$ level between students in the experimental group and students in the control group with students in the computer-integrated course scoring higher than students in the non-computer-integrated course. A possible explanation is that a higher percentage of males were in the computer-integrated course and a higher percentage of females were in the non-computer-integrated course while male SAT Math mean scores tended to be higher than female SAT Math scores. The covariate SAT Math is significant at the $0.0001 < 0.05$ level. There is a significant positive relationship between SAT Math Mean scores and the Fall 1993 Final Exam Mean scores. The mean common final exam score of the computer-integrated calculus students is 122.5 and the mean common final exam score of the non-computer-integrated calculus students is 114.0. The least squares
(adjusted) mean common final exam score of the computer-integrated calculus students is 121.9 and the least squares (adjusted) mean common final exam score of the non-computer-integrated calculus students is 115.2.

Furthermore, it is important to note that female students in the computer-integrated calculus course tended to have a higher mean score (122.0) than the females in the non-computer-integrated course (115.2) and male students in the computer-integrated calculus course tended to have a higher mean score (122.8) than the males in the non-computer-integrated course (113.2). However, the mean exam scores of male students (118.2) and female students (118.1) tended to be the same overall.
Figure 8. Mean Exam Scores Spring 1994

Common Final Exam Mean Scores Spring 1994

Table 11. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores, Standard Deviation (SD) and Standard Error (SE) Spring 1994

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>33</td>
<td>120.6</td>
<td>35</td>
<td>6</td>
<td>631.8</td>
<td>67</td>
<td>12</td>
<td>119.9</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>54</td>
<td>126.5</td>
<td>32</td>
<td>4</td>
<td>616.9</td>
<td>87</td>
<td>12</td>
<td>126.3</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>13</td>
<td>133.5</td>
<td>32</td>
<td>9</td>
<td>615.4</td>
<td>49</td>
<td>14</td>
<td>132.9</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>30</td>
<td>118.5</td>
<td>35</td>
<td>6</td>
<td>581.3</td>
<td>77</td>
<td>14</td>
<td>125.1</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>87</td>
<td>124.2</td>
<td>33</td>
<td>4</td>
<td>622.5</td>
<td>80</td>
<td>9</td>
<td>123.1</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>43</td>
<td>123.1</td>
<td>34</td>
<td>5</td>
<td>591.6</td>
<td>71</td>
<td>11</td>
<td>129.0</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>46</td>
<td>124.2</td>
<td>34</td>
<td>5</td>
<td>627.1</td>
<td>63</td>
<td>9</td>
<td>126.4</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>84</td>
<td>123.6</td>
<td>33</td>
<td>4</td>
<td>604.1</td>
<td>85</td>
<td>9</td>
<td>125.7</td>
</tr>
</tbody>
</table>
The graphs in Figure 9 illustrate that the male students in the computer-integrated calculus course had a higher SAT Math mean score than the males in the non-computer-integrated course and the females in both courses. However, Figure 10 indicates that the mean exam score of the male students in the computer-integrated calculus course was lower than the females in the computer-integrated calculus course and males in the non-computer-integrated course. In fact, the mean exam score of the male students in the computer-integrated calculus course (120.6) was almost the same as that of the females (118.5) in the non-computer-integrated course.
Method: Analysis of Covariance

Covariate: SAT Math

Dependent variable: Score (Common Final Examination Score out of a possible 200)

Independent variables: Type (Computer-Integrated or Non-Computer Integrated) Gender (Male or Female)

Level of significance: $\alpha = 0.05$

**Table 12. ANCOVA - mean exam scores Spring 1994**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MSS</th>
<th>F</th>
<th>SIG of F Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1</td>
<td>4168.401</td>
<td>4168.401</td>
<td>3.96</td>
<td>0.0487</td>
</tr>
<tr>
<td>Type</td>
<td>1</td>
<td>0.070111</td>
<td>0.070111</td>
<td>0.00</td>
<td>0.9935</td>
</tr>
<tr>
<td>Gen x Type</td>
<td>1</td>
<td>1201.523</td>
<td>1201.523</td>
<td>1.14</td>
<td>0.2873</td>
</tr>
<tr>
<td>SAT Math</td>
<td>1</td>
<td>6519.207</td>
<td>6519.207</td>
<td>6.20</td>
<td>0.0141</td>
</tr>
<tr>
<td>SAT Math x Gen</td>
<td>1</td>
<td>4618.456</td>
<td>4618.456</td>
<td>4.39</td>
<td>0.0382</td>
</tr>
<tr>
<td>SAT Math x Type</td>
<td>1</td>
<td>0.426</td>
<td>0.426</td>
<td>0.00</td>
<td>0.9840</td>
</tr>
<tr>
<td>Error</td>
<td>123</td>
<td>129382.759</td>
<td>1051.892</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Preliminary analysis with SAT Verbal as a covariate showed it to be not significant so it was eliminated from the final analysis.

The General Linear Model in SAS (used since there are unequal cell sizes) yielded the following results for the two factor analysis of covariance with two main effects:

* The covariate SAT Math is significant at the $0.0382 < 0.05$ level. There is a significant positive relationship between SAT Math Mean scores and the Spring 1994 Final Exam Mean scores.

* Gender is significant at the $0.0487 < 0.05$ level. However, since the interaction between SAT Math and Gender is significant and the relationship of SAT Math varies with Score depending on gender (positively for females and negatively for males), this is not reliable.

* Type is not significant at the 0.05 level.

* Interaction Gender $\times$ Type (0.2873) is not significant at the 0.05 level.

* SAT Math $\times$ Gender is significant at the $0.0382 < 0.05$ level.

* SAT Math $\times$ Type (0.9840) is not significant at the 0.05 level.

Therefore we must accept the null hypotheses and conclude there are no significant differences in achievement in calculus among subgroups in the Spring 1994 experimental study:

A. There are no significant differences in Spring 1994 common final exam mean scores between female students in the experimental group and female students in the control group;
B. There are no significant differences in Spring 1994 common final exam mean scores between male students in the experimental group and male students in the control group;

C. There are no significant differences in Spring 1994 common final exam mean scores between students in the experimental group and students in the control group;

D. There are no significant differences in Spring 1994 common final exam mean scores between female students and male students.

Two separate ANCOVA analyses - one for only female students and one for only male students- with SAT Math as a covariate, Score as a dependent variable and Type as an independent variable generated the following results:

* None of the factors Type, SAT Math and the interaction SAT Math x Type are significant with respect to Score for male calculus students.

* SAT Math is a significant effect with respect to Score for female calculus students at the 0.0035 <0.05 level; however Type and the interaction SAT Math x Type are not significant with respect to Score for female calculus students.
Students in Same Type of Calculus Course Both Semesters

Since some students switched between computer-integrated and non-computer integrated calculus courses second semester, the researcher did similar analyses including only the students who stayed in the same type of calculus course both semesters - either the computer-integrated or the non-computer integrated calculus course. In both semesters when Score is the independent variable and Gender and Type are the dependent variables SAT Math is a significant covariate at the 0.05 level and none of the other effects or their interactions are significant at the 0.05 level. However, figures (11, 12, 14 and 16) and tables (13 and 14) depict the tendency of students in all subgroups of the computer-integrated calculus course to have higher mean scores than those of students in the non-computer-integrated calculus course and female students to have higher mean exam scores than male students, albeit their mean SAT Math score is lower than that of male students.
Table 13. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores of students who stayed in the same type of course for both semesters, Standard Deviation (SD) and Standard Error (SE) Fall 1993

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>29</td>
<td>133.0</td>
<td>30</td>
<td>6</td>
<td>634.1</td>
<td>69</td>
<td>13</td>
<td>132.0</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>31</td>
<td>127.9</td>
<td>30</td>
<td>5</td>
<td>629.0</td>
<td>74</td>
<td>13</td>
<td>127.7</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>7</td>
<td>143.3</td>
<td>25</td>
<td>9</td>
<td>617.1</td>
<td>49</td>
<td>19</td>
<td>145.7</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>12</td>
<td>130.8</td>
<td>31</td>
<td>9</td>
<td>615.8</td>
<td>71</td>
<td>20</td>
<td>133.5</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>60</td>
<td>130.3</td>
<td>30</td>
<td>4</td>
<td>631.5</td>
<td>71</td>
<td>9</td>
<td>129.9</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>19</td>
<td>135.4</td>
<td>29</td>
<td>7</td>
<td>616.3</td>
<td>62</td>
<td>14</td>
<td>139.6</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>36</td>
<td>135.0</td>
<td>29</td>
<td>5</td>
<td>630.1</td>
<td>65</td>
<td>11</td>
<td>138.8</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>43</td>
<td>128.7</td>
<td>30</td>
<td>5</td>
<td>625.3</td>
<td>73</td>
<td>11</td>
<td>130.6</td>
</tr>
</tbody>
</table>
Figure 15. Mean SAT Math scores of students in same type of course both semesters Spring 1994

Figure 16. Mean exam scores of students in same type of course both semesters Spring 1994

Common Final Exam Mean Scores Spring 1994

Table 14. Mean final exam scores, SAT Math mean scores, Adjusted (Least Squares) mean exam scores of students who stayed in the same type of course for both semesters, Standard Deviation (SD) and Standard Error (SE) Spring 1994

<table>
<thead>
<tr>
<th>Gender</th>
<th>Type</th>
<th>Number</th>
<th>Mean Score</th>
<th>SD</th>
<th>SE</th>
<th>SATMath Mean</th>
<th>SD</th>
<th>SE</th>
<th>LS Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>C-I</td>
<td>26</td>
<td>120.9</td>
<td>37</td>
<td>7</td>
<td>634.5</td>
<td>69</td>
<td>14</td>
<td>120.9</td>
</tr>
<tr>
<td>Male</td>
<td>Non-C-I</td>
<td>29</td>
<td>119.3</td>
<td>34</td>
<td>6</td>
<td>627.2</td>
<td>76</td>
<td>14</td>
<td>119.4</td>
</tr>
<tr>
<td>Female</td>
<td>C-I</td>
<td>6</td>
<td>139.3</td>
<td>41</td>
<td>17</td>
<td>621.7</td>
<td>52</td>
<td>21</td>
<td>141.0</td>
</tr>
<tr>
<td>Female</td>
<td>Non-C-I</td>
<td>12</td>
<td>121.1</td>
<td>36</td>
<td>10</td>
<td>615.8</td>
<td>71</td>
<td>20</td>
<td>124.8</td>
</tr>
<tr>
<td>Male</td>
<td>Both</td>
<td>55</td>
<td>120.1</td>
<td>35</td>
<td>5</td>
<td>630.7</td>
<td>72</td>
<td>10</td>
<td>120.1</td>
</tr>
<tr>
<td>Female</td>
<td>Both</td>
<td>18</td>
<td>127.2</td>
<td>38</td>
<td>9</td>
<td>617.8</td>
<td>64</td>
<td>15</td>
<td>132.9</td>
</tr>
<tr>
<td>Both</td>
<td>C-I</td>
<td>32</td>
<td>124.3</td>
<td>38</td>
<td>7</td>
<td>632.1</td>
<td>65</td>
<td>11</td>
<td>130.9</td>
</tr>
<tr>
<td>Both</td>
<td>Non-C-I</td>
<td>41</td>
<td>119.9</td>
<td>34</td>
<td>5</td>
<td>623.9</td>
<td>74</td>
<td>12</td>
<td>122.1</td>
</tr>
</tbody>
</table>
An Attitude Questionnaire was completed by approximately 44% of the students in Math 115Q, Math 115V, Math 116Q and Math 116V - first and second semester calculus- the last day of classes in Fall 1993. Courses with the letter "Q" denote the non-computer-integrated calculus course and courses with the letter "V" denote the computer-integrated calculus course. The questionnaire was developed by the University of Connecticut Institute of Social Inquiry. The 163 students responding included 93 in the computer-integrated course (37 female and 56 male) and 70 in the non-computer-integrated course (28 female and 42 male). Interviews were conducted with calculus students during Spring 1994 to gain insight into the responses on the attitude questionnaire (Appendix B). The 40 students who participated in the confidential interview included 21 in the computer-integrated course (8 female and 13 male ) and 19 in the non-computer-integrated course (10 female and 9 male). Seven students were in the computer-integrated course first semester and in the non-computer-integrated second semester; 2 females and 5 males. Six students were in the non-computer-integrated course first semester and in the computer-integrated second semester; 2 females and 4 males. Thirty-five interviews were taped and conducted in person at the University of Connecticut. Five taped telephone interviews included three students in the computer-integrated course (2 females and 1 male) and two
students in the non-computer-integrated (1 female and 1 male). Quotes from the interviews are included with the quantitative results.

Notable percentage of frequency results of all calculus students responding and significant Chi-square results are listed and followed by breakdown by subgroups with corresponding quotes from the interviews.

Notable Percentage of Frequency Results of all Calculus Students Responding

<table>
<thead>
<tr>
<th>Agree or Strongly Agree</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>83.0%</td>
<td>A6: Good math teachers show students lots of different ways to look at the same question.</td>
</tr>
<tr>
<td>81.2%</td>
<td>A35: My calculus course is helping me understand the basic principles of calculus.</td>
</tr>
<tr>
<td>80.6%</td>
<td>A16: My calculus class gives me thinking and problem solving skills.</td>
</tr>
<tr>
<td>80.0%</td>
<td>A36: In the long run, I think taking calculus will help me.</td>
</tr>
<tr>
<td>80.0%</td>
<td>A47: I find a career in mathematics, science or engineering attractive.</td>
</tr>
<tr>
<td>79.4%</td>
<td>A12: My calculus class really requires me to think about what I am doing rather than just plugging numbers into formulas.</td>
</tr>
<tr>
<td>73.9%</td>
<td>A20: My calculus class is preparing me to take higher level math courses.</td>
</tr>
</tbody>
</table>
72.7% A19: My calculus course requires much more thinking than memorization.

72.1% A10: Some people are good at math and some just aren't.

70.3% A43: I like to help others with math problems.

69.1% A29: I am getting a secure foundation in the basics of calculus.

68.5% A49: When I take a math course, I usually get a good grade.

67.3% A37: My calculus class is forcing me to learn a lot of material.

66.1% A42: I enjoy trying to solve a math problem.

65.5% A31: My calculus class gives me a good understanding of what calculus is all about.

64.8% A3: What I've learned in calculus will be useful to me after I've finished the course.

64.2% A4: My advisors in high school encouraged me to take math courses.

61.8% A17: I enjoy doing math problems.

60.6% A8: After I've forgotten all the formulas, I will still be able to use the ideas presented to me in calculus.

60.6% A14: In math you can be creative and discover things by yourself.

56.4% A9: I feel I can apply what I've learned in calculus to real world problems.
Disagree or Strongly Disagree

84.2%  A32:  Math problems can be done correctly in only one way.

77.6%  A33:  Understanding of concepts is of little or no value on the tests in my calculus course.

70.3%  A18:  Most of what is presented to me in calculus is too difficult to grasp.

70.3%  A44:  Men make better scientists and engineers than women do.

67.9%  A27:  My calculus course should be covering more material.

64.2%  A34:  I see no practical use for what I'm learning in my calculus course.

62.4%  A11:  To solve math problems you have to know the exact procedure for each problem, or you can't do anything.

60%   A13:  I find what we learn in calculus to be dull, uninteresting and a chore to learn.

50.9%  A15:  My calculus class is boring.

A breakdown of notable percentage of frequency results of all respondents and corresponding quotes from the interviews follows by the following subgroups:

CF (female students in the computer-integrated calculus course),
CM (male students in the computer-integrated calculus course),
NF (female students in the non-computer-integrated calculus course),
NM (male students in the non-computer-integrated calculus course),
C (students in the computer-integrated calculus course),
N (students in the non-computer-integrated calculus course),
F (females in the calculus course), and
M (males in the calculus course). Quotes from the interviews are included.

Agree or Strongly Agree

<table>
<thead>
<tr>
<th>Agree or Strongly Agree</th>
<th>A6: Good math teachers show students lots of different ways to look at the same question.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>83.0%</td>
</tr>
<tr>
<td>CM</td>
<td></td>
</tr>
<tr>
<td>NF</td>
<td></td>
</tr>
<tr>
<td>NM</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>81.1</td>
</tr>
<tr>
<td>N</td>
<td>87.5</td>
</tr>
<tr>
<td>F</td>
<td>85.7</td>
</tr>
<tr>
<td>M</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td>85.1</td>
</tr>
<tr>
<td></td>
<td>80.3</td>
</tr>
<tr>
<td></td>
<td>83.1</td>
</tr>
<tr>
<td></td>
<td>83.7</td>
</tr>
</tbody>
</table>

CF

"I think you can approach it usually from other directions."

CM

"It has been brought out in this class by Professor ( ) that there's more than one way you can go about a problem. It's kind of refreshing because if you don't know this one way (it's not just only a, b, c, d) there also are alternate routes. I think it's encouraging because it's less constrained."

"Teaching teamwork and how to get along gives you different points of view that you might not come up with. Like I said, there's more than one way to solve a problem."

"Usually there are several ways of solving it."

NF
"There's more than one way. Try another way."

"There are always different tracks."

NM

"You have to try different ways. In math there's a lot of different ways to solve a problem - there's not just one way."

"A lot of times there's more than one route to get to an answer."

81.2% A35: My calculus course is helping me understand the basic principles of calculus.

<table>
<thead>
<tr>
<th>CF</th>
<th>CM</th>
<th>NF</th>
<th>NM</th>
<th>C</th>
<th>N</th>
<th>F</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>81.1</td>
<td>82.1</td>
<td>82.1</td>
<td>78.6</td>
<td>81.9</td>
<td>80.3</td>
<td>81.5</td>
<td>80.6</td>
</tr>
</tbody>
</table>

69.1% A29: I am getting a secure foundation in the basics of calculus.

<table>
<thead>
<tr>
<th>CF</th>
<th>CM</th>
<th>NF</th>
<th>NM</th>
<th>C</th>
<th>N</th>
<th>F</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>64.9</td>
<td>75.0</td>
<td>71.4</td>
<td>64.3</td>
<td>70.2</td>
<td>67.6</td>
<td>67.7</td>
<td>70.4</td>
</tr>
</tbody>
</table>

65.5% A31: My calculus class gives me a good understanding of what calculus is all about.

<table>
<thead>
<tr>
<th>CF</th>
<th>CM</th>
<th>NF</th>
<th>NM</th>
<th>C</th>
<th>N</th>
<th>F</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>64.9</td>
<td>71.4</td>
<td>60.7</td>
<td>61.9</td>
<td>68.1</td>
<td>62.0</td>
<td>63.1</td>
<td>67.4</td>
</tr>
</tbody>
</table>

"Now I'm learning why - not just how to do - not just blank memorization of routines and formulas but you know the proofs behind them
you understand the concept why and how to use this idea how to apply it -
you're not just looking at it through equations but through graphs which
display them - so you have broad understanding

"Especially this class because you came away from it knowing calculus
- and a little bit more I think - because you knew how to do what everyone
else knew how to do - you knew how to plug numbers into the formulas and
do the techniques - but you also knew a little bit behind that - what the
techniques actually did and who were the people who came up with them
and how did they come up with them. (I was comparing my class to others
here and in high school.)"

" The things I have learned have helped me in other classes like
physics and chemistry. When they say you could use calculus to do this, I
know what they mean by learning it here in certain situations."

"Differentiation and integration is more than moving all the numbers
around and changing the powers. It's interesting how it relates to velocity
and acceleration."

" It integrates different aspects of calculus and I understand how
everything is somehow related."

CM

"Fundamentals started right from beginning. It was taught really well.
I understood it and I didn't forget it. I still understand everything. The
combination of computer and instructor - the computer helped to see it -
what goes on when something is approaching a limit - and it was taught well."

"That's where the theory part comes in. You're seeing how math is built and where these things come from and how they're important to real world problems and solving - velocity stuff - physics problems and engineering problems. The derivative is the rate of change."

"Seeing it for the second time - I had it in high school - parts I didn't see the first time are being made clear and other parts are being reinforced."

"Definitely. The way the class is presented, it followed in an evolutionary sense - not only mathematically but historically."

"Yes. For example to understand $x \sin x$, look at the graph and zoom in with the computer."

"I will see when I get to the next level."

NF

"Our teacher goes over the theory behind everything. Once you understand the theory you understand why it happens."

"I didn't understand why behind it. As soon as he started to explain things to us, it all fell into place and made sense to me. I had a much better grasp on it."

"Half of the semester I had already done in high school - but it was amazing how much more I learned by doing it here. It seemed like before in high school I memorized stuff whereas here I can get a picture of it in my mind and do it."
"Most of these things are the backbone of calculus we covered both semesters."

"I thought they were well explained, for example, when Riemann sums were drawn out on the board. I see things more clearly when things are drawn out. I need the pictures."

80.6% A16: My calculus class gives me thinking and problem solving skills.

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79.4% A12: My calculus class really requires me to think about what I am doing rather than just plugging numbers into formulas.

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72.7% A19: My calculus course requires much more thinking than memorization.

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"This one does - in 115Q if you did your homework problems and memorized the homework problems you could pass the tests, but in 115V you have to understand what is going on behind it because on the tests he asks questions so you have to know what is going on - you couldn't just memorize it. You have to understand why as well as how."

"You can't just sit in the class and absorb it. It definitely takes a lot of mental gymnastics. Just to do the homework at night takes a lot of thinking. Just to sit in class, actually, because the professor often opens up to discussion or says, 'Can you help me with this?' I find that he doesn't stand up and just lecture, lecture, lecture. A lot of the times he'll just say, 'OK, now what do you think?' and so you can't just sit there and say, 'Well, I wasn't thinking this period.' So you always have to stay on your toes. It's easy to fall behind in this calculus class if you don't."

CM

"Definitely - because you have to understand. Anytime you have to understand something then you have to think about it."

"You have to think about what you're doing - especially the lab portion of it where we are using the computers. You can't just plug in numbers. They always give you questions that make you think."

"Definitely - they don't give you everything. You have to think. When they test you you really have to know what you're doing."
NF

"Word problems make you think."

"It's just a formula that you have to apply - sometimes you can do it routinely - but then when things are more complicated then you're going to have to understand more."

NM

"In a way, yes. You get into a lot of problems. You have to think back to what you have learned before and how it would work in this problem."

"I think it does - even more first semester because I had to get into the depths of what the theorem was saying in the computer-integrated course."

"Yes it's an analytical course - sometimes I can do it from memory - other times I do it by understanding."

80.0% A36: In the long run, I think taking calculus will help me.

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73.9% A20: My calculus class is preparing me to take higher level math courses.

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What I've learned in calculus will be useful to me after I've finished the course.

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"Definitely. I am a science major so I find applications of calculus every day in chemistry and biology classes. I use the calculus in those courses."

"Analysis - problem solving - I don't know if I'll need the formulas."

"I'm not too sure with pharmacy. If I work in a community pharmacy it's not likely to help, but if I did work in a research facility, yeah, it would come in handy."

"For my major, computer science, I have to go to Calculus IV, so this is just the beginning.

"Oh, yes. It applies to chemistry. Recently in chemistry we were using logarithms and antidifferentiation. We were trying to plot a titration curve using computers. We had just done that in calculus 2 or 3 weeks ago. Yeah, it does carry over."

"Being a mechanical engineer, I'm going to use calculus every day."

"Everything uses some level of math - calculus develops thinking on in-depth problem solving. You can relate that to a lot of other things."
"It teaches me how to think and use logic in my career."

NF

"I'm going to major in math."

"I am going to be a civil engineer. I need to build structures."

"In plant science, now that I understand calculus, I understand exponential and logarithmic graphs more in-depth and population ecology k values make more sense."

"I think it will, probably in my job later on in the natural sciences."

"To an extent. Some of it does apply. I'm a biology major so I'll probably have to work with formulas if I go into the medical field - how much of a dose do you give to a patient - I can see that - maybe I'll need to do more (with) computers"

NM

"In grad school industrial organizational psychology research."

"I can see using it later like growth and decay in biology"

"The applications in chemistry and physics are fairly widespread."

80.0% A47: I find a career in mathematics, science or engineering attractive.

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Among the students participating in the interview 90% answered yes - CF 87.5%, CM 92.3%, NF 90%, NM 88.9%, C 90.5%, N 89.5%, F 88.9% and M 90.9%. Some of their choices include:

**CF**

"Mathematics - I want to teach high school math. I love algebra."

"Mathematics and science better than engineering."

"Science."

**CM**

"Computer science."

"Engineering."

"Software engineer."

"I've always loved science, math - everything."

"Science - chemistry."

"Mechanical engineering - designing engines and gears."

"Mathematics teacher or mathematics professor."

"Science. Biology systems I find very interesting"

**NF**

"Biology."

"Something with computers - use statistics - ecology or even insurance. I like everything that uses math."

"Engineering - my father is an engineer. I'm going for pre-med."

"Engineering."

"Science."
"Engineering, science and mathematics."

NM

"Mechanical engineering designing machines."

"Science research."

"Engineering."

Science or engineering - geology major.

72.1% A10: Some people are good at math and some just aren't.

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CF

"Anyone who can work hard can do it, but it does take a certain kind of thinking. If you're just going to sit there and memorize equations, you're not going to get it; but if you look at it with an analytical mind, then it's easy. You come out with a different product. The people who memorize probably forget it but if you have developed your own thought process you can really use in other classes and other areas."

"I believe there are those that have a talent for mathematics; but I believe that everyone can reasonably do mathematics if they work hard. I'd like to take myself as an example because I don't think I'm very talented as far as mathematics goes; but when I work at something I'll get the answer with everybody else."
"Anyone can actually do the math if they work hard enough; but a lot of people can't grasp it as well and they'd have to spend a lot more time and some things just aren't graspable to some people. I know I've always been able to grasp math. I know a lot of people who are really smart and really intelligent and they work really hard and they still can't grasp it. Their brain thinks another way instead of mathematically. My friend worked hard and failed calculus."

"Definitely there are those who have a knack for it or are good at it; but I think just about anybody can do anything if they put their mind to it. It depends on how much you want something. Unless somebody has a learning disability I think people have that ability to learn. If they really want to they can."

"I think that some people are naturally good at math; but I don't think it's actually the math. I think it's being able to visualize the concepts. I think some people just can't visualize it."

"Definitely some are naturally good and don't have to work. Then there are others like myself who do."

CM

"Always if you work hard on something you will get better but to get excellent at something you have to be sort of gifted."

"I think it's easier for some. I don't know if it's because they have less clog in their brain, because they're thinking mathematically because they can think mathematically or if they're just smart. I don't think everyone gets it.
the same. I don't think if person A studies five hours and person B studies five hours they're going to know exactly the same thing. I don't think it's a time constraint."

"I think anybody can get by in math if they work hard. I think there's a little bit where there's some people that are better. There are some people who can really do it then there are some people - they take a while but they still get it...but everyone has to work hard at some point or other, so I think anybody can do just fine. They can get through it."

"Some are naturally good and some aren't. The same with music - some are and some aren't. Some people that aren't can work real hard and get good grades and others do nothing and they understand things. I told the people I was helping to sit down and do problems - a lot of them - every single problem in the chapter. It's tedious. It takes a while - but it works."

"Some people just give up easily... I think if everyone works hard they can do a little better...I feel that society accepts people who are 'bad' in math but if you're 'bad' in English that's almost looked down upon. I think people give up a lot in math. They don't try hard enough. It might take them longer but most people can get farther if they work harder."

"There are people with an advantage of picking up things quicker than others; but if you set an equation down in front of an average intelligent person and tell them what to do with it they could do it, and, with enough practice, they could do it on their own. The difference comes when you ask them to do a problem above what they've done before learning. Tests here
have problems harder than what we've seen. You have to have a mastery and complete understanding; but you also have to have thinking skills to be able to solve a different problem. That would separate the average person. Anyone can take a derivative if they are given a formula and told exactly how to do it; but if they're given a derivative that's a little more complicated—one different from what they've seen before - the person with more natural ability can do it. If you have natural ability at math you see things faster and don't have to practice as much - you see different things that people who aren't as good at math don't see."

"Anyone who works hard can do it but it definitely comes to some people more easily than others."

"Some are naturally good at it; but if you work at it you're going to get better. Some people think they are extremely poor at it and use it as an excuse not to go into it."

NF

"Some are naturally good and others are not. I'm not naturally good at English and other people are not naturally good at math. If they worked hard they would be able to get it, but they would have to work harder than others who are naturally good at it"

"Some people have the natural ability. I have to work hard at it. It's like clicking in over time."

"If you work hard enough at it you can understand it. You don't have to have an inborn ability to do it. In middle school I had a hard time. I
wasn't mathematically inclined, as they say, but I'm doing ok in my classes. I think if you're willing to do the homework and try and go for extra help when you need it, especially when you're confused, go straight there instead of waiting a week or two and try to follow along with what he is trying to say, you can do at least C or B work. I had difficulty when I started algebra but after that - as long as you do the work - I have been making A's in all my math classes since; but I wouldn't consider my self a mathematical person."

"I think if you like it or not makes a big difference. For some it's drudgery. What one thinks may be not in a mathematical way. If they wanted to I'm sure they could learn how to think in the way that could help them in mathematics. They may have to work harder but they are still capable of it."

"Some have an attribute for it."

"Anyone that works hard I think can get it. It's just that people who are naturally good won't have to work that hard."

"There are some people who are born to be mathematicians. They just always think in that way. They are computer oriented. I have friends who are good at computers and math. But I believe anyone can be good at math if you just work at it - if you keep on trying. I'm not that good at math, but I do the work and, if you do the work, you can become good at it."

"Some people have some magical power - they just see it and they're - "Oh this is so easy ha ha and I did all my homework." Sometimes I struggle
and I can't even get through the homework no matter how many hours I spend. I don't know. Some people are just born to do math, I think, but I think that, also, if I work hard and put in the time, I'm sure I could get an A in 115 and 116. But I just don't have the time. I don't want to give up everything else in my life so that I can get an A in math."

"Some are naturally good at math and others are not. My boyfriend is extremely intelligent and has a lot of genius within the arts but math is just not his cup of tea. Some people have a natural inclination toward the arts or the sciences - one or the other - generally. If you have a natural inclination to the arts, yes, you can do math, but it's not as easy. It's possible. But I have to work hard and I have a natural inclination in math. Someone who doesn't would be pulling their hair out because to do well in math they would have to put in three or four times as much effort as I do and then they're not going to practically get any of their other classes done. They could if that was their only class."

NM

"Math comes easy to me but it seems like if you work at it it could come easy."

"I think there are some that are naturally good at math, but then there are others who, if they do work hard, they will be able to do math if you're determined to do it. I remember one point in my life - I hated math. I couldn't do it. After I said, 'I like math' and then got good at it."
"Some are naturally good. Some take a lot longer. I know for me it takes a while to learn something. Some people get it just like that. I know I can get to a level in math. I'm not so sure I can go on into the higher level that math majors take. I don't think I could be a math major."

"I believe some people are naturally good at some things and other people aren't. Yeah, people have different strengths and weaknesses. Most people can get through high school math. It's a case of ambition and interest. I find I don't do things as well in things that I'm bored of or don't find interesting. I think because it's hard to get people interested in it, you'll find that people probably prioritized calculus last. I'm just guessing. When I'm bored of something I put it last. It's a difficult subject to teach."

"I think a lot of people clearly understand math concepts and principles; but I think, if you work hard enough, at some point you can start to understand a lot of it. I don't think I was born with a talent to do math but I think I can learn everything if I really gave it all. I don't think calculus is as abstract as people say. It is a lot of work, but it is not totally abstract."

70.3% A43: I like to help others with math problems.

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"Sure, if I can. I know that in our homework discussion groups that meet at night it's really great because if one person gets it then they'll write it up on the board and show every one and I like to be able to sometimes say, 'Oh, I got that one', and I'll put it up for everyone to see. It makes you feel good to be able to show people something that maybe they didn't get on the first time around. If you can explain something to someone or show them how to do it then that proves to yourself that you have the best understanding of how to do it. So there's no weakness or there's no doubt in your mind that you don't know how to do it."

"I don't mind really. I know how thankful I am when someone helps me with a problem no matter how trivial it is or how hard it is. I believe that no question is a dumb question. If you are in school they are there for you to learn. I've had situations where TA's have said, 'I can't believe you don't know that.' But I don't think that's appropriate because I'm asking because I don't and if it's a dumb question then I won't ask again because I will know the answer. I don't mind helping people because I really appreciate help myself - because I'm one of those people who doesn't hesitate to ask for help because things don't come to me necessarily at the snap of a finger. I have to work hard for anything I get. I ask questions all the time. You may as well use your resources while you have them."

"I don't think so. I'm not good at it. I understand what I'm talking about, and a lot of times it's hard for me to tell them the same thing. That's
the only reason. I like help with others. I'll know it really well. I'll go to tell them. Sometimes I'll help. Other times they just don't see it. I get frustrated when I don't know how to explain it."

"Yes. It gives me a sense of accomplishment that I actually understand it and it helps me understand it better when I tell them. It kind of makes you think about it more."

"If I understand something, sometimes I can explain it a different way than the professor, TA or whatever - and if that helps a classmate then I'm all for it. When I verbalize what's in my head, sometimes I find mistakes in what I'm thinking, so it helps clarify."

CM

"Yes. I like to help to see how good I am."

"Usually - depending on the problem and also on the people - learn more that way. Some people see things that you won't see. That happens a lot in lab."

"Yes, the way I see it is not every one is good at math, so I try to help people who aren't. I'm good at math so I try to use what I know. It's kind of a review and the more you review the better it sticks with you."

"As long as I understand what I'm doing - if I don't understand what I'm doing I'm not going to help them very well."

"Sure. If they don't understand I figure someday I'm not going to understand so it would be nice if someone would help me. So sure if somebody doesn't understand then I'll help them. It just reinforces what you
already know. Get as much of it as you can so it will stick in your head and you'll remember it."

"Yes, I love teaching in general. If I have a problem on one of the problems, if someone can explain it to me I can go on and stop fretting on it. Yeah, if I can do that for someone else, I'll always take the time to do it. If you can explain and get the point across to someone you understand it better."

"Teaching people also helps to teach myself. Yes. I was helping these two people study for a test. I did it. They understood it just like that. Yes I got my point across which is supposed to happen when you're learning."

"Yes, I want them to feel the sense of accomplishment also. I just like helping people in general. It's just my personality. It forces me to work. It helps me to think."

"I like helping people. That's why I'm going into psychology. I think when you teach things your understanding goes up a level."

"It's nice to help somebody understand something that they couldn't see before. Teaching is one of the best ways to learn."

"Chances are they're going to have insights you don't quite recognize and they can help you along with it. Yeah, well help is a very subjective term. Hearing their questions helps you to understand better."

"Whenever you teach someone else something you usually learn something yourself and that reinforces something - whatever it is that
probably you've already had or you've just had and since most things in calculus and math carry on, fortunately, that's pretty good!"

"I always enjoyed it in high school. Even now I like to help people. I'm pretty good at explaining things and using analogies for teaching. I help friends the next level down a lot."

NF

"Yes, if they're having a problem I'll show them to help them out. If I were stuck on a math problem I'd want someone else to help me."

"I do at home - my brothers and sisters. You know, it's funny going back because they're in high school and I remember I couldn't do those problems in high school and now I can whiz right through them. I see that they have a problem with math as I did in high school and I feel good that I'm able to help them."

"It makes me feel smart. I like helping others. If you have to explain it to someone, you have to explain it to yourself."

"I like to show them when someone is confused about something. I like clearing it up for them, helping them along."

"No, I live an hour away. I am twenty years older and I don't hang out with students."

"It enforces it in my mind if I can explain it without the thing right in front of me. I know if I can explain it to someone else I know it's in my mind for recall."
"Yes, it helps them to better understand. Sometimes they can't see how you get it, but you have to explain it a couple of times and they finally get it. It does help me."

"I do when I know how to do them. I like to help people if I can help them in any way because I feel good that I have this knowledge that I can help them with. When I study for a test I study with my roommate and sometimes she doesn't understand things and I explain all these things to her and I find that when it comes time to take the test it really helped me a lot to repeat it and do all the problems for somebody else because if you're teaching it you obviously have to know what you're talking about."

"If I completely understand it I think it's great because I like knowing that another person understands it because I in some way shape or form helped them. But if I'm having a hard time with the material myself it's like first I want to concentrate on getting it down for myself before I help you because I might confuse that person more and I might confuse myself more and it's just not a pretty sight."

NM

"I like to see people learn. It just feels good to share your knowledge - you know? At certain times they ask you questions - you've got to think."

"It's the best way for me to review what I learned before. Sometimes I help them so I don't even have to do my homework to understand the concepts."
"It's great teaching someone and at the same time you learn more about it yourself. That's the great thing about teaching."

"I think I do. It shows that I am capable of doing the problem. Helping others or coming up with an answer to a problem together is a sign of progress."

"Not really. Tutoring isn't my thing. I understand it. I know how to do it. I actually enjoy doing them sometimes, but I don't like teaching it. I don't want to be a teacher or professor."

"Before I couldn't help anyone. Now it's nice to know you have a knack for it - you can show people how to do stuff. Just like hearing them say, 'Oh, ok, that's how you do it!' It's like, 'ah'.

"If I know how - I enjoy helping people when I can because I have something to offer to someone else."

"When I get something out of it I guess, but in general no. I'm not that great at it, so I rarely help people. Actually some of the calculus 1 students I do help. Now that you mention it, it is a lot of fun because it makes me feel like I learned something last semester."

"If someone needs some help and needs something explained to them I don't mind doing that. Teaching someone is a good way to learn - not basics. In talking and explaining to someone about something you're becoming more familiar with exactly what you're talking about."
68.5% A49: When I take a math course, I usually get a good grade.

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Percentages among students who were interviewed were similar.

66.1% A42: I enjoy trying to solve a math problem.

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61.8% A17: I enjoy doing math problems.

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"I love mathematics. It's exciting to be able to solve a problem - actually get it out on paper - be able to do things - be able to discover formulas on my own and actually get a problem finished - the fact that it goes along with the applications - that I can use it. So I love it. It's an exhilarating feeling to solve a problem. It's not like most of the other majors where you ok memorize and you do this - it's more of a 'I'm going to think' and it's great. I thought it out. I did it myself. I finished it. I got it done. It took a lot of brain power to do it and a lot of thinking - and I like that. I like to accomplish things like that."
"It uses different thinking skills that you wouldn't use in another class. It's a little puzzle basically and you solve it. It can be fun."

"Yes and no. After about two hours you don't enjoy mathematics any more - but to do the homework every week is not a chore for me. It's interesting. I'd like to think that I'm motivated as far as doing the homework and labs go because there's kind of this - you want to do it. If it gets long or it gets hard or it gets tedious I have the tendency to get frustrated and I want to give up but you have to finish things so it always gets done somehow. I like to turn in a paper or homework assignment with my name on it in a show that I got everything done or at least tried all of them. that shows that you put in a really good effort on your part. I think that's all a professor can ask."

"Yes, it's not my favorite thinking to do but I don't dread it. I like that there is an exact answer to a problem - not subjective like other classes."

"Yes, I get a sense of achievement after I do problems."

"I like it when I can figure out what I'm supposed to be doing but when I can't do a problem I get frustrated and I like being able to go talk to someone with office hours or somebody you can see. I'm not an English type person - more science and math - so I just enjoy the problem solving part of it. I like working with numbers."

"I'm good at problem solving in a very set way like that. I'm pretty good at it so I like what I'm pretty good at. I get a sense of accomplishment and like being challenged."

100
"No, I have a hard time. I get frustrated. When I get a problem I feel good. I feel I've achieved something. I feel good about it."

CM

"I love it. I've always loved it. The way I look at it - it's just another puzzle to solve. It's kind of interesting. It's fun.

"Yes, I have a scientific mind. I was a fine arts major before and didn't have the confidence and didn't get the pleasure out of it that I do in doing math problems. It's nice to have an objective point to get to and once you get there you know you're done. With fine arts I struggled with it forever even after I was done with it. I presented it and still felt like it wasn't enough and I didn't feel good about it. I know the math is done - I've gotten the right answer and I can't do any more. It's kind of nice to have the finality of it."

"Yes, it seems like fun to play around with different parts of math."

"Yes, I don't know. People call me stupid. It's fun solving problems working on something really hard - and getting right answers is really cool. You're sitting down frustrated drudge your way through it - check your answer and it's right - and you're psyched - I can't explain it. Most people are against math and freak out when you say math but I like it. Of course I get frustrated when I don't understand it, but that's normal."

"I used to. I didn't have to work as hard. It came very natural to me. Now I have to work harder."
"Sure. It's a mental challenge. Its kind of surprising sometimes the things you can do if you work on a problem for a while you play around with it - you can come up with different ways of expressing it you might have not noticed before - you can just think about things in different ways. It's surprising. I get a sense of accomplishment."

"Sometimes it's interesting. I like creative problem solving."

"It depends on how much time I have - If I don't have to do it I can like it depending on the mood I'm in. I like to understand. The concepts will be useful in engineering If I get it right and understand the concepts."

"Well I don't do it well too often so that takes away from the enjoyment. When I can understand something and get it right I really enjoy it - the accomplishment of getting something right that was difficult - doing something I know not many other people can."

NF

"Yes, if I understand it. If I don't understand it I don't like it too much. It's easier than other things for me."

"Yes, mathematics is logical. It feels like you've accomplished something when you get an answer. It's more logical and it's more definite."

"Sometimes when I get the answers right. I like solving problems and getting answers. It is inherent in me."

"No, I never enjoyed math. I can't see it. I can solve equations but I can't do word problems. There has been an antagonistic relationship - me toward math. Last time related rates was worst."
"Usually it makes me feel like I've accomplished something when I understand a problem. In the grand scheme of things it will help me to be a doctor because it's the building blocks of what I want to do."

"I used to. I loved it in high school. That was one thing I was really good at. I used to want to be a math major. Now I decided not to."

"I used to. It's been a tough year. this year with math. In high school I did well in math and I enjoyed it."

"When I understand I do. I have to understand what I'm doing. If I don't understand I go for help day in and day out until I do understand. When I don't understand it I'm really frustrated because I'm not accustomed to not understanding mathematics. I'm accustomed to getting something first try and that's it. To have to put a little more effort is frustrating, but I do it anyway. I enjoy getting the right answer and understanding how you got it and why you got it and the fact that you did get it. It's the feeling it's a challenge and you fulfilled it."

NM

"Yes, some of the problems are challenging and I like it to be challenging. So once you get the answer even after hours of work you feel good."

"When I get it right, yes. When I understand it, definitely. It's fun learning it because it's something new. It's always nice to learn something new and say - even if you think you might not be able to use it in real life it's always nice to say I can do this. You're doing more than somebody else can
do. That's the way I look at it. People look at math and say, 'Weird letters and symbols' and I can say, 'Yeah I understand this.' And that's what is the fun thing about it."

"Yes, it's like a challenge. You sit down and try to do a problem and get an answer and use different methods of doing it. I really like doing the math."

"Yes, I always have. I enjoy being challenged. I can do something I couldn't do before."

"When I was younger I didn't, but when I got into calculus I started to enjoy it more. I was a math 101 jock - basic algebra freshman year. I did horrible in that class - I got a C minus. I just decided to get my bachelor of science last year. I was scared, but once I got into it, it was really cool. I'm a senior now."

"It depends - if it takes me a half hour to do a problem I start to get impatient - but I enjoy less abstract math more than calculus - trigonometry and geometry."

"Yes and no. I do when I can figure out the problem but right now I'm not motivated. There's not much use for it."

"I despise doing mathematics. I don't like to think. I'm an intellectually lazy guy. If someone were to pay me to sit home and read poetry all day long I would."
67.3% A37: My calculus class is forcing me to learn a lot of material.

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64.2% A4: My advisors in high school encouraged me to take math courses.

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60.6% A8: After I've forgotten all the formulas, I will still be able to use the ideas presented to me in calculus.

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60.6% A14: In math you can be creative and discover things by yourself.

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"I'd like to think that I can because on the tests you have to be able to. A lot of the times they throw in questions that are a little bit tricky - that involve maybe thinking about something in a different manner and definitely takes creativity."
"Yes, usually what I discover I learn about later in class. I love that. That's why I love math."

"I can. Whether or not I do is another story. I have the ability."

"Not really. It's pretty structured."

"Sometimes. I don't know if I really try to. But one time in class I gave him a new way to derive something and he was all impressed with that but other than that I follow what's in the class. (I felt) kind of surprised. You have to be creative in order to answer the questions - you have to move things around. I'm not creative when you try to discover new methods of calculus."

"Sometimes I see a connection with some other aspect that I've learned before. It's encouraged in the course."

CM

"Sometimes."

"I think there is room to be creative. I myself am not particularly able to do that because I am not at the level of understanding as some other students in this course. So I think the avenue is there. I just don't know if I myself can be able to do it. The possibility is there."

"Once in a while I get lucky and stumble upon something. That feels good. It's like, 'Oh, wow.' And it finally clicks and you go, 'Yeah I can do this.' So it's kind of neat."

"No, I don't feel comfortable enough. I don't have confidence to do it.
Professor () is wonderful about that. When students bring things up he'll follow through with that to show there is more than one way."

"Yes, every now and then. It's fun. But sometimes it doesn't happen on a test."

"Yes, we play around in class, experiment and discover a little. Cool."

"Definitely - there are a lot of different ways to do things - Professor ()'s attitude completely makes our class this semester. Creativitywise the professor leaves a lot of room for us to explore and experiment - try different things with problems and see they don't work and why they don't work. He lets us be creative and makes sure we keep on the right track."

"Sure playing around on the computer helps with that - manipulating equations and seeing how the graph changes."

"Certainly. There have been periods earlier in the course where they'd be wading through a proof on the board for the next material and there'd be several of us sitting in a group thinking "Hey, I could have derived that. That's not that hard!" Yes, it's kind of interesting - the way the mathematician's mind works in a certain way and the proof certainly encompasses tools that I'm familiar with and everyone else in the class is. And yeah I think it really is a creative endeavor especially concerning some problems. Yes, unfortunately the professor sometimes doesn't do it and I get irritated."
"Yes, there's usually so much material they basically have to set you up to discover something - which does happen. You think about something and see it before it's covered in class."

"In high school you moved much slower, understood the concepts more fully before you moved on to something else - and here you don't really have that much time to reflect on something. You have to think about next step - you just think about then and now."

"Yes, it happened working on a problem I thought I could never do. It makes you feel good. No one else in class got it."

NF

"No."

"Sometimes."

"No, not with math I just see numbers and I can't think of different ways to use numbers. It's just there on a piece of paper and you just solve it."

"Probably not. I find the subject hard so I follow how its taught and try not to do anything else myself because i'd probably get confused if I did."

"Not often. I need to have it pointed out to me."

"They would allow you to but I don't. The opportunity is there."

"Yes, a lot of times you can use tangent or replace by sine or cosine as long as you follow the rules."

"I guess if you asked me to. I don't know I've never tried to. First semester was more (conducive to being) creative and discover. We used a
computer. You couldn't just take a formula you got in class and solve the problem. It wasn't that easy. You had to understand what you were doing and apply it to the computer. You had to know what you were trying to find and sometimes it would take a lot of different things. You had to really know what you were doing."

"Not usually - both of my teachers give suggestion to try. I don't usually follow up on them because I barely get the homework done but I'm sure there are some people out there with a lot of initiative probably that try some of those things out."

"Yes, I do but it always is good to have someone else's opinion because not everyone has the same insight."

NM

"I like to think so, yeah. I don't think this course lends itself for me to do so."

"Yes, you can make up some sort of problem. You feel good because you can do it faster than other people."

"Yes, both semesters if the book says to do it one way I try another way to see if it will work."

"Hmm, not really as far I can see right now. The formulas are already there - just use the formula and apply it to the problem you are given - probably not that much.

"Yes, if I get lucky sometimes."
"My creativity isn't that great. Teaching myself - I can do that, but discovering a different way is a little harder."

"Sometimes I understand what's coming in the book. There's not enough time to think about things too much."

"Sometimes. I'm not that creative. Sometimes I figure harder problems out - rarely though."

"A lot of times what happens is I have to be creative. You can't tell me this equals that. I want to know why and I go back and find out why they got from one step to another."

56.4%  A9: I feel I can apply what I've learned in calculus to real world problems.

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"Sure because any of the real world problems that I'm going to be faced with in the next few years will probably have to do with my occupation which will hopefully be in the sciences. Aside from that, you can't live I think in this world without mathematics. It's just all around us. So the better understanding you have of mathematics I think the better understanding of your environment you have."

"Yes, they show you in the text and in classes."
"Yes, to a degree maximum area and things like that."

Eventually. I don't think I'm going to stop and figure something out. But I think it will all be helpful as background. In the course a problem to figure out speed - to figure out if someone was speeding or not ... It was the first time I was like, 'Wow maybe you can use this in your life.' "

"Yes, physics...chemistry... ph... titration curves."

"Not the calculus itself. The problem solving aspect is useful - following a logical step to get an answer and dividing things up in steps to solve a problem"

"Possibly, yes it could help with physics and engineering."

CM

"Maybe - it's useful for programming."

"Definitely. You need it for electrical engineering and physics. You can do more complex things with it than without it."

"Yes and no. I mean yes I know I can find the maximum area for a box but I don't think there will be a time when I do that. I don't think I will find the length of shadow while standing under a light. Real problems are difficult to do because there are so many different majors in one class."

"Of course being a liberal arts student I can look at the general horizon about the whole thing. You can approach these things differently. It makes you more of a man or whatever or a better human being because you can approach life and don't freak out and not get all upset and depressed if you
don't know one way of doing it. More realistic - annual funds - financial matters which will have a place in my financial life my future."

"Yes, I think so. I haven't used it much in real situations but I always felt it did. Looking at different word problems you can see how it would apply to different things."

"Yes, as mundane as the quickest way across this field - ph - I see it through the problems."

Yes, dad and I do work on house, build a deck, design things - do things around the house trailers and car."

"Yes, just any thing. You go to psych class - standard deviation - areas under curves."

"Sure if nothing else, if I ever have children, I can teach them calculus. In class he'll give us chemistry examples, physics examples, car accidents."

"Yes, relate the coordinate plane to real world events like the derivative and motion and acceleration, sine functions for engineering. It's easy to apply a lot of the stuff. I used to be crassly annoyed with math and physics because of the chaos factor - a previous hangup - none of stuff is completely accurate anyway!"

"To some extent - volume."

"If I go into engineering definitely."

NF

"No."

"Yes, physics and working in a job that uses math."
"Probably not."

"Yes. In my other classes like chemistry there's integration and velocity and acceleration in physics.

"Yes, that is a real world problem - papers on denitrification wetlands work out derivatives of equations which now I can follow. It's used a lot in science."

"Sometimes yes. I don't know if someone else would use it like I do. There was a telephone message for my roommate "going to be home between three and four o'clock - have her call me then." I wrote the limit as x approaches t, t equals time, of f of x equals when X< 3, don't call; when x is between 3 and 4, call; when x > 4, don't call; and I drew this time line where it shows home - not home - it's kind of silly it's not that practical, but it's funny to do because it actually worked - like a functional math problem. She thought it was hilarious to fool around with stuff like that. I like to do it."

"Yes, maybe in my job."

"Not day to day. If I were an engineer - but no not really."

"Well sure, especially when It comes to physics you just take a derivative and you've got velocity - take another one you've got acceleration."

NM

"I don't think so."

Yes, sure. Usually we learn it from the problems from the class like going to the bank."
"I don't know about the direct materials of calculus, but calculus stimulates your thinking process finding different ways to solve the problems."

"Not right now - maybe job related problems - acceleration, velocity, strain, are occasionally mentioned in class."

"Yes, it's applied in physics class like velocity."

"Yes, I think calculus is usable for everyday problems."

"Not really - growth - decay."

"If I were worried about maximizing the size of my yard - sure, but in the real world you go out and buy an acre of land - it's laid out and you don't have a chance to maximize the fence. They try and try and try to give feasible situations but as for myself I don't see any real world problems outside of academia."

Disagree or Strongly Disagree

84.2% A32: Math problems can be done correctly in only one way.

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A44: Men make better scientists and engineers than women do.

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No, I believe we are both equal."

"No, a long time ago girls were taught how to read and how to write to be focused more on the humanities and more on the social sciences. Men were brought more toward mathematics and the scientific part. But now that we see that the roles of society are changing and a lot more women are in the sciences we see that men and women are equal in intelligence and the abilities in that area."

"No, I'm an anti anti-feminist. Women can do just as much as men as far as I'm concerned mentally. It all depends on the person."

"I think society stereotypes men to be smarter than women in certain realms of education but I think I find women who are good in math and science tend to explain things better than men do."

"Not necessarily. They were brought up to make better ones. Women are just as capable and just as smart - actually - better because they give a different light to it."

"No, I think that women are led away just because of the way it's been. I think now there's more women in science than there ever has been - but I don't think men do it any better. There's only three girls in our calculus class."
I'm sure the three of us probably have the three highest averages. I'm not positive but I know our averages are among the top. So I think the girls who want to do it can probably do it better than men because they know they're competing for things so they have to work harder. And I don't think men are any smarter than women."

"Not really. Right now that's the way it seems, but it seems to be changing a lot. I know just about as much calculus as any male in the class if not more. It depends on the person - not the gender."

"No, it's a stereotype that men are better at math than women. Just as many men are failing in our class as women."

CM

"I don't think that. I see some women do pretty well. My TA is a woman."

"No, why not? The girls in my computer science classes do better than guys do actually."

"No, this is the 90's. Sex has nothing to do with it and it's been proven."

"I don't think I'm qualified to answer that. The only engineer I know is my dad and he's a guy."

"Because men are typically traditionally brought up the way they are - that being trucks, little toy trucks - this is a bridge you build this with Legos - this is a model you build the model. In that sense they have a learned appreciation and enthusiasm for what they're doing. Anytime you have
enthusiasm you're going to be a better whatever it is. In that sense they may
generally be more adaptable - more adept to engineering. I don't think it's
necessarily a sexual characteristic - it's more of a social societal type of thing.
When I look around at kids that have always been in my classes I look at the
females and I look at the men and I look at myself it would be a very
hypocritical thing to say that the women aren't capable of doing it because
they're kicking my butt in these exams."

"I don't know. I have no idea actually. I don't think so. All that I've
seen is that there are more men in math classes that doesn't make women
any less capable at all."

"No a lot of people in the news media are promoting that they're
taught that way. We're all equal I guess."

"No, sex doesn't matter. In teachers women connect better - maybe a
mother instinct - well maybe with guys at a younger age."

"I don't think it has anything to do with gender at all. I think you can
do anything. It's a matter of how much time you're willing to put into it."

"No, in specific instances there is no real difference; but it does seem in
general males pick up math easier than females - females pick up language
easier - just from what I've seen in my schooling and my siblings - entirely
individual."

"In the United States in the present culture men are more encouraged
and that in turn produces more scientists that way - we have a couple of
women in the class who can outdo pretty much anybody - there's not any
disparity in ability. It seems to me a lot more emphasis starting from way back when - there are a lot of studies about this kind of thing and I've talked to some parents about this and they've identified this sort of stuff where boys in 1st grade are picked out when they raise their hand and so on and even though teachers try not to there pretty much is preferential treatment pretty much all through the grades. So I think that's probably a pretty leading cause - social pressures - sociological phenomenon."

"That's a generality. In the general aspect women see things differently, but several see things step by step logically - and a lot of men don't either - but you tend to see a lot more men in engineering anyway. Personally I understand men - so I see them as being logical - you have to be very logical in engineering. To me it follows."

"No, they both have equal amounts of intellect and there's no reason men should be better than women."

NF

"No."

"No, not necessarily. It doesn't matter if you 're male or female - just if you like math or if you understand it."

"That's a hard question. I don't know. I think they would be just as good. There's not too many of them. I noticed that in a lot of my math classes and even my science classes it's the females students who are participating not so much the males."
"I think that's what most people believe because most engineers now are males; but I think a female engineer could be just as good as a male engineer."

"No, we're brought up that way. Men are guided in that direction. I think whether male or female - what that person wants to do - is capable of anything whether it's math or English."

"No, not so much a male female thing. Some people can see it and some can't."

"No, we all have same capacity in our heads. It all depends on what mind set you set up for yourself ahead of time - what blocks - like, 'Oh, I'm a girl.' If you don't have that then you're all set."

"No, even though there's a lot of men - the women have better grades- I was surprised to hear that. There's nothing different with men and women. I don't think it depends on the gender. It's your intelligence."

"I wouldn't say so. No. Men ad women are equal. I see just as many smart girls as I do guys."

"No, and you know what I have to face? Every time I go to get a job in engineering is the fact that there are always going to be guys who go, 'You're a chick. You can't do math.' And that's stupid. What makes the male gender more capable of doing a math problem? Who says that a woman wouldn't have been able to make up all that Newton knew if she hadn't been pushed down and stepped on ever since the dawn of time. Women were not encouraged or pushed or allowed to express their genius even up to now."
Women still have a hard time expressing their genius because of gender roles. Who's to say what mathematical geniuses have been lost because women were not allowed to express their knowledge. So no definitely not. Men do not make better engineers."

NM

"Not necessarily. Both sexes have the ability to learn. Neither of them is superior."

No, it's not the sex. It depends on the person. You try hard like any one else."

"No, men and women are equal in ability." 

"No, I don't think so. Actually there aren't a lot of women engineers as compared to men engineers as far as I've seen in my classes. But from what I've seen I think they may even have a better work ethic than we do. They might even be better. I don't know."

"No, I have a friend. She is a very good engineer. I think she is going to be a good engineer and better than most guys I know. I think a lot of women are geared away from engineering because it is supposed to be a masculine thing. It's something guys have been in for a long time. Girls would tend to shy away from it. I see my friend. She is on the track team. She's got like a 3.6 average in the school of engineering. That says a lot. I don't think she's too worried about competing with guys. It doesn't affect her. She can compete with guys on the track team. I think if women can get by that - the stereotype of women in engineering - I think they can."
"My opinion is everyone can do as well as anybody else based on the education they've received and how much ambition they have. I don't think it's gender specific."

"No, given the opportunity I've seen many women that can do just the same kind of work."

"No, I don't think there is ground to say something like that. Why would they make better scientists, mathematicians or engineers? The fields are all about people using their minds. There's no gender restriction on brain activity. If you want to talk about hormonal tendencies to dominate or be irrational then you might be able to make an argument somewhere for one versus another - but if your not talking about a hormonal study then I don't have any grounds to say that."

64.2% A34: I see no practical use for what I'm learning in my calculus course.

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Please see quotes on pp. 86 - 88.

62.4% A11: To solve math problems you have to know the exact procedure for each problem, or you can't do anything.

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"No, most of the times you can get part of it by looking at the problem. Take the things you have learned and try to put things together."

"No, because there's always such a thing as partial credit and it seems that if you can demonstrate enough knowledge of how to begin a problem or sometimes even how to end it, if you can put the numbers in some kind of coherent order then that's one step closer to getting an answer. I never leave a blank space on a test. I try to use any other techniques or knowledge that maybe wasn't discussed in the chapter that's surrounding the problem - or try to go back and think of any little loopholes that you can use in order to figure it out. A lot of the times you just have to guess and then scratch it out and say no and then try it again. Trial and error works."

"No, a lot of times you can finagle your way through somehow. As long as you're calculating you can stumble upon the answer. Sometimes in a roundabout way it comes back to the answer. You start doing the problem and realize that's exactly what needed to be done."

"No, a lot of times I try to figure out to the best of my ability what I think should happen. I go with that and hope it's close to what I'm supposed to be doing. If it's not sometimes I think it's almost good to get it wrong. When I make a mistake and am shown the right way then it sticks in my head as opposed to doing it right to begin with and putting it in the back of my mind. I remember it better."
"No, I think you can approach it usually from other directions. Sometimes you can just figure it out using what you know because usually if you use what you know you can at least get halfway through it. A lot of times there are new concepts that you can't do. Math is progressive and you can usually go back and use what you have learned before."

"Some problems - but some you can figure out because you understand the calculus - you don't have to know the exact thing - you just have to have an idea of it - then you can piece things together and figure it out."

CM

"Try to see if there is a way to come up with a formula."

"I happen to think not. You should never have to completely memorize anything as long as you understand concepts."

"No, there's stuff that you try to blend from other math courses. There are other ways to do problems. We try to break them down into formulas or ways that we do know. It might be two problems combined. First we try to break it down and try to do something with it and try to go on from there if possible."

"No, you can sit there and play with it a little bit and work it into something more useful. It depends if your totally lost there's nothing you can do - go to someone for help. I like to work at it at least. Use a little common sense. That's important too - to remember what you learn so that you can apply it."
"No, it's a different way of looking at the world. Try to break it down and figure how to attack it first."

"No, I just play around and see what I can do with it and use logic to see my way through homework problems or mainly on a test - and tests are basically homework problems with a major twist in them that throws you off. I see and I take my time and if I don't understand something I try to break them down in to simpler concepts. Sometimes it doesn't pop into my head to take a different route which is a route you're supposed to take and I'm lost. And after I realize - what if I do this to the problem - and it comes right out. Yes!"

"No, fiddle around until you get something. Try different things. Try different formulas. Try doing algebra to change the formula. Ask someone. It's the best way to learn."

"No, do different things. Simplify as much as possible. Break down into smaller parts."

"No, you can either make something up or apply any mathematical process you know until it changes into something you can do. Even if it's something I have never seen before I can try to do something with it."

NF

"No, try another way."

"No, because I've had times when I've made up my own formula and it ended up being right."
"No, I can sometimes figure things out. It might take a while. When I'm stuck on a problem and can't figure it out, I try different methods maybe a method I used a couple of weeks ago on another problem."

"No, you can always try something else - basically trial and error. If something doesn't work then try something else. Try different ways."

"No, fool around with it and see what else you can make out of it. I write down anything I know and put it together."

"No, I just try to put down something. They're pretty good about giving partial credit. I try basic things I know, for example, substitution to get it in a way that I recognize and do something with it."

"No, you can work on it up to point. I try as many ways I can think of. If it doesn't work try another way. If I can't get it I ask for help."

"No, that's not true. There's got to be some way you can solve it. Sometimes you're at a dead end but then you can just think of how you've solved other problems and apply it somehow. Just using common sense also."

NM

"It depends. You can use different procedures for different math problems, so if one procedure doesn't work use another procedure which you know better."

"No, you have to try different ways. In math there's a lot of different ways to solve a problem - there's not just one way."
"No, I always feel I can do something. I try making up things. I put anything in there. I love trying to do it my way. This semester I have been more successful."

"If you don't know the exact procedure I think you can do something. If you have an idea of what should be going on you can always do something. Not one formula applies to a math problem. You can always use what you know from some other formula or some other concept and get some answer even if it's not right."

"No, generally you should be able to figure something out with it or at least start on the problem given a general description of what you should do. With logic there should be a way to do every problem. If you have done something related to that you should be able to solve it."

"If I don't know the exact procedure I think I can still solve the problem. A lot of the procedures - there's different formulas you can use - like lots of tests for series."

"No, it never hurts to take a stab at a problem - there's always more than one technique in solving a problem - I muddle through."

"No, I try to figure out generally what's going on - basically looking at the overall problem - looking at where it is going - and hoping that I can somehow figure out the formulas that will lead to it."

"Not the case in calculus. A lot of times there's more than one route to get to an answer; and if you start on something a lot of times you can get it into manageable form. I use L'Hopital's rule a lot of times."
60%  A13: I find what we learn in calculus to be dull, uninteresting and a chore to learn.

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50.9%  A15: My calculus class is boring.

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"I like the computer portion of this course a lot because of the fact that it takes you away from the books for a little while and allows you to use media that is a little bit different. It's a little bit exciting too because instead of turning pages you're clicking a mouse on an icon or something and it's just a nice change. And I find that I learn a lot from the computer just because I'm interested and it's fun."

"In this class the professor is excellent. He explains things to us both in class and in the computer lab. It's kind of like a change in environment. It helps you learn better. You're not just writing things off the board. You're actually seeing how things work."

"Challenging is the first word that comes to mind because it is harder than any other math course I've had before. A lot is expected of us. But
we're adults now and should be able to handle it. As I was talking to a couple of my friends in the class they were like 'Hey aren't the math problems starting to get fun?' I was like 'Yeah it's scary - calculus is starting to become fun!''

"Confusing. It takes lots of work. It's more work with the computer."

"Interesting. They don't mind taking time out to make sure you understand. I never walk out of class not understanding and if I do there are office hours available."

"It's very challenging. I'm not a math major or an engineering major so I didn't really need to take it. It's very difficult - it's very challenging. I really don't know why I take it now that I'm in it, but I was very interested in and I liked it in high school and I thought I would take it to fulfill the requirement. The class is small. It's very good that way. We can ask questions that way. There's lots of openness. I think the TA is a very good instructor. His set up is very organized. He states definitions and theorems and examples to support them. Generally speaking I think it's a well designed class."

"Frustrating. I'm not math oriented. I work very hard and I don't do very well at the university. I did in high school. I'm trying to do what I have to get my degree."

CM

"I have been actually - almost frighteningly so - enjoying some of calculus because it's getting advanced enough to the point where solving
problems is a creative endeavor because there are many many ways to check out one thing - well if this doesn't work we'll try this and so on."

"It helps motivate you too because you don't think this is worthless and a waste of time. You see that you really do need it so it's not just for the test."

"It's kind of fun. It's interesting. I like math. Good teachers. The computer makes it more interesting. You see it with all the graphs."

"Interesting and lately in the last semester somewhat more dynamic with his choice to present us with problems as the lecture progresses rather than lecturing and showing us examples. That's one thing I'm very glad that he has started to do. Unfortunately he can't always do it - a lot of the times it's very interesting to - we'll be going over a certain concept and he'll say, 'Well you have some of the basics, let's see if as a class we can do, say - this.' More often than not, we usually come up with doing it a different way and admittedly to himself sometimes a better way than the way he would have planned to show us. He was going to include at least one example we had figured out in the next edition of the text. There was some proof we worked out in a different and somewhat more efficient way than he had shown it. And he was pretty happy about that."

"After fifteen minutes of lecture stop. Come up with a problem relevant to the lecture of the day. He previously had not shown us how to do any of these but he would imagine that with material he had given us so
far we might be able to extrapolate that into a method to solve the problem.
I like that a lot."

NF

"Calculus I find challenging but I do like it - but I must say though this is the first math class I've ever liked. I've never been a math person. It's kind of weird but kind of good. If you have any questions he doesn't mind if you interrupt him and answer the questions - easy going so you're not uptight in the class. You don't get stressed out in the class."

"He's very good. I enjoy the instructor."

"I like the class a lot In high school I didn't "get it" but here my teacher is so good I got it right away."

NM

"Compared to any other class that I've taken on campus - a little more intense. When you go to class you're paying attention to get the gist of it because you know if you don't get it then it's something important that's going to be on the test or something that's a link on the chain of things that you have to understand - a preparation for my own real studying - it lays the foundation for my studying."

77.6% A33: Understanding of concepts is of little or no value on the tests in my calculus course.
Please see quotes on pp. 84 - 86.

### A18: Most of what is presented to me in calculus is too difficult to grasp.

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### A27: My calculus course should be covering more material.

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Quantitative chi-square tests were analyzed for significant differences among subgroups in the calculus course. Detailed tables and results are given in Appendix D and Appendix E.

Chi-square analysis yielded significant differences between genders on the following questions (computer-integrated (C-I), non-computer-integrated (N-CI)) (Appendix D):

A 20: My calculus class is preparing me to take higher level math courses.
All: Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed.
C-I: Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed.

N-Cl: There are no significant differences between gender and responses to A20 in non-computer-integrated classes.

A 24: Good math teachers show you the exact way to answer the math questions you'll be tested on.

All: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.

C-I: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.

N-CI: There are no significant differences between gender and responses to A24 in computer-integrated classes.

A 27: My calculus course should be covering more material.

All: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.
C-I:  Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

N-CI Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

A 32: Math problems can be done correctly in only one way.

All: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.

C-I and N-CI:
*There were no significant differences in the computer-integrated and non-computer-integrated subgroups.

*Warning: 50% of the cells have expected counts less than 5 in the computer-integrated group and 67% of the cells have expected counts less than 5 in the non-computer-integrated group. Chi-Square may not be a valid test.

A 44: Men make better scientists and engineers than women do.

All: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.
C-I: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

N-CI: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

Chi-square analysis yielded significant differences between students in computer-integrated and non-computer-integrated calculus courses on the following questions (female students (F), male students (M)) (Appendix E):

A 21: My calculus course covers too much material too quickly.

F: Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected agreed or disagreed with the statement. More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected were neutral.

M: There are no significant differences between the type of course male students are taking and responses to A21.

All: Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected agreed with the statement. More students in the computer-integrated
course than expected and fewer students in the non-computer-integrated course than expected disagreed or were neutral.

A 50: My family always encouraged me to take math courses.

F: More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected disagreed.

M: There are no significant differences between the type of course males are taking and responses to A50.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected disagreed.

The results for C 3, C 8 and C 9 were the same:

C 3: How often do you use a computer at school for numerical computation?

C 8: How often do you use a computer to graph a function or equation?

C 9: How often do you use a computer to do symbolic manipulation?
F: More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time.

M: More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

C 7: How often do you use a calculator to graph a function or equation?

F: There are no significant differences between the type of course females are taking and responses to C7.
M: More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

Students' Comments on Using the Computer

CF

"I think that the computer in the V section helps a lot. The reason that I took it is not only because it covers your C (computer) credit here at the university but it makes what may be like a black board textbook science more interesting because it's more interactive now and you can manipulate the numbers and change everything by using the computer. It makes it more attractive and more fun for me. The course had been recommended by a friend who took the course before."
"The computer does ... in a matter of seconds what it would take an hour by hand ... advantages of seeing perfect graphs and tangent lines. All the functions are there and you can see how they are used. I have computer phobia. If someone is there to help me I would prefer to use the computer any day."

"There are programs to see things a lot easier. It's a lot easier to understand things and it makes it faster. For series - put it in the computer to see if it converges or diverges. The graph of $e$ to the $x$ - just to refresh your memory - just plug it in to get ... what it looks like and just go on and do the other problems."

"It certainly makes things easier; but I think that in the way we're using them right now we could get along without them. But it just takes a great load off our back as students as far as computation and doing out lists and lists of numbers and data points- just to be able to put in to the computer and then to be able to see something like a graph. Aside from that I think it is a luxury almost."

"The graphs if you did by hand would take forever. Just put it on the computer and you can see it. It helps you relate more to what you're doing in class. Three dimensional things are easier to visualize and understand better than on the blackboard. When we do labs in class it makes sense - it's more helpful than when we do them on our own; they're more complex - it never works - I get so frustrated."
"The computer doesn't help me that much. I don't always know what all the numbers mean. It's easier to use a graphing calculator."

"Basically it's not as I thought it would be. The programs are pretty much in there. You just run them and that's it. It's not like we work with them. The graphics help to understand concepts to a certain degree a little, not a lot."

CM

"Computer models definitely help - for graphing of functions in particular. Students should actually be encouraged to go in and try to learn some of the programming for themselves... if they have to learn to program it they have to learn it."

"Graphing is best part of it. You can see 3 dimensional graphing easier. To visualize with the computer some equation you would never be able to graph by hand ... you can actually learn the theory better."

"I use a MAC in lab - an IBM in my dorm room. With my own software - given data find summation over time - use an integral. I use the computer for anything that requires interpolation because calculators do not have enough power. I know C and PASCAL. The computer labs help a lot to visualize certain things - some of the abstract stuff that we cover - if you didn't see on a computer - if you didn't see this is how it works with this or that and show you a graph of it - an application you might see it - some people do - I don't think I would."
"The computer is very helpful in graphics and trying to estimate limits that would be impossible to do. I use a computer more than a calculator. I have a computer of my own and I feel comfortable using a computer. It's more powerful."

"I use a computer for computer projects and in lab. It's helpful for me for graphs. It makes it more comprehensible."

"It's interesting to see how they (computers) work and all the programs to help with the visual aspect where you can see all the graphs worked out - how they work. It's neat to see how they get the computer to do it. It puts a picture to the numbers. It's kind of nice. Here you are working with all these equations - that's all they are - just equations. You kind of take a break and say, 'This is actually what it looks like. This is what it does.' It's kind of a practical thing because you can see what they look like and what they're used for more on the computer than - 'Here's an equation. Play with it a little bit.'"

"The computer lab breaks down the process so you can do it step by step and it speeds up the process. It's nice because you can visualize a lot of different problems. A majority of the programs are graphing programs, so for things we aren't able to graph yet, we're able to see theoretically what we're doing."

"It saves time for many repetitions of same things like using Newton's method. The computer is faster than the calculator. The computer makes it visual. We do a lot of graphing of functions as demonstrations of
approaching limits and stuff like that. Shapes of polar graphs help to understand concepts of calculus. It's more advantageous to use computers to learn calculus."

"It is interesting to see how the computer is used for relevant real life applications but for most part. I like it but it's a sort of a selfish way to like it. More often than not using the computer to say, 'Well we have this technology now so it's useless for you to have to go through all these mindless calculations when you can hit 2 or 3 buttons and get the same answer.' More often than not the computer lab is shown that we have program available to eliminate work and undue suffering on our part doing anything particularly nasty a goo degree. Newton's method - usually we stop after two or three increments by hand. He says, 'Well in 12 seconds or less we can do 18,000 and have this ridiculously accurate answer. It seems to me it's a tool for learning, but a lot of it is to remind us of the presence of the technology and to eliminate undue work - which is good and bad. Sometimes it would be helpful to do more practice so that we would be able to understand completely what's going on with the computer when we use it. It's a small fear that I have that if it advances to a point where we do quite a bit of the stuff on the computer the students might become somewhat disconnected to the processes involved in the calculations and might not actually understand what's going on... I have to concede it's not terribly often that the computer brings a mathematical epiphany of something I hadn't noticed before. As a computer it's not a creative tool just a workhorse tool.
It's handy - its nice to see the graphs done completely accurately. It's a good tool to integrate a lot of information that normally might take a long time to calculate very quickly ... because if the point of the lecture is to examine whatever topic, it holds the student's interest longer and I think it's helpful that the other rudimentary calculations are expediently dismissed.

"Sometimes the computer is helpful. You can see things easier or when you first learn it you understand the concepts quicker. Labs don't usually reinforce things. They don't always have relevance. Last semester it seemed like a waste. There was just more work to do. This semester it does relate more."

"I don't like the computer part. I'm not a math or engineering major. I'm just taking calculus for fun. It's a lot of work and hassle in getting together with 5 other people."

NF

"I would try to see how to use computers with math. I think it should be required for all math classes to have it. If I had a choice I would take the computer-integrated course. Nowadays computers are very important. To learn how to use them with math would be beneficial."

"Last semester for labs ... it was pretty helpful. It sort of helped to understand calculus better for some parts of it. You see it on the computer. Sometimes it helps - sometimes it doesn't. Limits could be understood better with the computer."
"I didn't want to do the computer lab any more... It might have given more insight, but I didn't think it was worth it. Learning the techniques of using the computer was useless for me. I would have preferred to spend time learning more calculus."

"Last semester I didn't enjoy the computer lab experience at all. It added an extra load - the hassle to write up a lab and go down twice, three times a week on your own time to meet so that you can get the labs finished. It was not helpful for me - I wasn't caught up to understand the lab. It wasn't until I studied everything that it started to click and by then I'd just end up cramming."

NM

"The computer last semester helped a lot to solve equations like you don't know the roots - the roots are real hard to find - you put it into the computer and it gives the roots real fast - and graphs - equations that would take a long time to plot the points - put into the computer and you get the graph real fast. Built in functions - use them, change the range, zoom in ... (For the) bisection method - if you didn't have the computer you wouldn't know where to start - which end? It's valuable."

"The computer in last semester's class was great. I expected to learn what to do with computers - learn how to use it to do other things. I could do it if the professor was there, but not if he wasn't. I used the computer last semester to see what the graphs of certain functions looked like and how
they related to the first and second derivative. From there we looked at more graphs and how they related to each other. I got to see pictures of things - which is always helpful I think. This semester it would help to an extent. Last semester we were introduced to a lot of different things so it was more helpful then. This semester we're doing one thing in a lot of different ways."

"Last semester it was a lot of work because we had computer labs. A lot more material was covered in more depth, especially theorems - which I don't like - getting in depth. It helped to understand derivatives but not really - I didn't really get much from that."

"The computer didn't help me at all. It was just following instructions and it didn't back up any theories. It was just plugging formulas into the computer and spitting out equations. It was pretty useless. It was just a waste of time. Instead of another hour I could spend it on something else."

Students' Comments on Using the Calculator

CF

"Any calculations I have - I always like to check things - trig functions and logs. It simplifies. It's easier quicker and more reliable."

"Saves time on tests."

"I use a calculator for numerical computations too big and too complicated for anything I want to do by hand. I use a TI 85 graphing
calculator for homework. I don't own one so I don't use it on tests. It has a lot of similarities with the computer."

"A graphing calculator is helpful. It is more efficient if you're doing things that deal with graphs but graphs are not the problem. It's helpful to get a picture of the graph and go on with the rest of the problem. It makes it more efficient - easier."

"I use a graphing calculator for visualizing graphs, doing computation, and evaluating trig functions on homework and exams."

CM

"Raw computations, evaluating sin, cos. The Casio graphing calculator does some of the same things as the computer to an extent. You get higher resolution with a computer and it goes a lot faster. Also, if I can't get something to work out on the computer I can write it myself; whereas on this (calculator) you can write it to an extent, but it's not as flexible. I use it on exams. There is not much you can really do with it. Graphing helps to an extent - but not really."

"I use a graphing calculator on tests to make sure I have plotted functions correctly."

"I use a TI-81 graphing calculator when I do my homework. It is helpful if you're stuck on a problem. You can see the graph of a function or it helps you visualize it. The calculator I have is kind of neat because you can see all the numbers when you add it up. If you make a mistake you can just go back and change it, so that's kind of nice."
"I use a graphing calculator sometimes when I can get it to work. not terribly more than just for number crunching functions and some of the other particularly nasty graphs. It's handy; but other than that I can pretty much do without it. It's not as if it eliminates any thought processes. It's more along the line of doing rudimentary calculations that look particularly nasty or choosing some other method to check the answer of what I had just calculated. I couldn't do all the work without a calc by any means on homework and tests."

NF

"It's helpful - less thinking on my part - faster - check answers - clear mind for more thoughtful processes."

"Computation is faster."

"It's not required on tests."

"For functions - sin, cos, logs - and computation it is definitely helpful - faster and easier."

"Not much - a little for big numbers. It makes computation a little easier. I use it to check little things to avoid careless errors when I'm nervous on a test."

"It's not necessary. The numbers are so small and we leave answers as exact answers."

"I used the TI - 81 first semester - we were allowed to use graphing calculators on tests. Now I don't use a graphing calculator. A graphing
calculator is more useful for me to do graphing and programming - like Newton's method."

"The graphing calculator is helpful. I do my graphs on there. It's easier to see what it looks like. It's easier for me to see it than to plot every point and draw it out and still have time. It makes things easier for computing. I have been able to use it on tests both semesters - only certain types of graphing calculators are not allowed on tests."

NM

"It's not needed to express answers in exact form - trig functions of special angles - for logs leave as log 10 (for example)."

"I use it all the time for arithmetic, trig functions, logs. It helps me to do calculations faster and more accurately."

"To calculate trig functions, powers, and roots, ln, log, and computation - I'm more sure of the answers. It makes things easier to do. The quickness of it ..."

"It's helpful - computes faster - saves time - cuts down on error."

"It's helpful with problems, number crunching, trig and log functions for speed and accuracy. I use it on tests and homework"

"I don't need it - even for trig functions either semester."

"I typically don't use a calculator for this class - I use fractions. Occasionally I use it to cross check - rarely on tests."

"I think calculators and computers are helpful once you learn fundamental skills in a course, but I'm learning those fundamental skills. I
prefer learning fundamental skills with a pencil and paper just like I did in elementary school because it becomes a crutch if you don't know those skills prior to using the machine."

Summary of Significant Results by Hypotheses

Common Final Examination Scores

I A 1. There are significant differences in Fall 1993 common final exam mean scores between students in the experimental group and students in the control group; students in the computer-integrated calculus course had a higher mean exam score than students in the non-computer-integrated calculus course.

Subsequent Courses for Which Calculus is a Prerequisite

II D. There is a significant difference between the mean number of subsequent courses (for which calculus is a direct prerequisite) taken by female students and the mean number of subsequent courses taken by male students. There is a significantly higher mean number of subsequent courses (for which calculus is a direct prerequisite) taken by male students than by female students.
III D. There is a significant difference in the mean average grades in subsequent courses between female students and male students. Female mean average grades in subsequent courses were higher than mean average grades of male students.

Attitude Questionnaire

The results for questions C 3, C 8 and C 9 were the same:

C 3: How often do you use a computer at school for numerical computation?

C 8: How often do you use a computer to graph a function or equation?

C 9: How often do you use a computer to do symbolic manipulation?

F: More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time.

M: More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.
All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

C 7: How often do you use a calculator to graph a function or equation?

F: There are no significant differences between the type of course females are taking and responses to C7.

M: More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.
Other significant attitude questionnaire results obtained by chi-square analysis are listed on pages 131 - 137. Notable percentage of frequency results of all respondents are delineated on pages 73 - 75 followed by a breakdown by subgroups with corresponding quotes from the interviews on pages 75 - 131. Results and conclusions are presented in Chapter V.
Chapter V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

The purpose of this study was to find, analyze and disseminate information pertaining to relationships between gender and achievement and gender and attitudes in a computer-integrated first year college mainstream calculus course in comparison with a similar non-computer-integrated course. The investigator analyzed data from pilot and experimental studies conducted at the University of Connecticut at Storrs in 1989 - 1993 and 1993 - 1994, respectively, in order to compare the computer-integrated calculus course and the non-computer-integrated calculus course with respect to student achievement and attitudes with a particular focus on gender. Both quantitative and qualitative methods were employed. Instruments for the quantitative research include the common final examination scores and the attitude survey. The statistical analysis method of the quantitative data is ANOVA/ANCOVA. For the qualitative research, the investigator interviewed students to gain insight into their attitudes about their calculus course specifically and mathematics education more generally. The dissertation research investigated, with a particular focus on gender:
1. how student achievement in a computer-integrated calculus course compares with that in a similar non-computer-integrated calculus course;

2. how attitudes of students in a computer-integrated calculus course compare with those of students in a similar non-computer-integrated calculus course;

3. how enrollment in subsequent courses for which calculus is a direct prerequisite compares between students in a computer-integrated calculus courses and students in a similar non-computer-integrated calculus course; and

4. how performance in subsequent courses for which calculus is a direct prerequisite compares between students in a computer-integrated calculus course and students in a similar non-computer-integrated calculus course.

The results were as follows:

1. Achievement

Quantitative analysis using ANCOVA indicated that SAT Math scores were significant positive predictors of final exam scores in Fall 1989, Fall 1993 and Spring 1994.

There were no significant differences among subgroups in achievement on common final exam scores in Fall 1989 and Spring 1990. This implies that although there was no improved mastery of the conceptual mastery for the
experimental group in Fall 1989, there was no decline in the mastery of traditional computational techniques for the experimental sections in Spring 1990. The Fall 1989 final exam was concept-focused; whereas the Spring 1990 final exam stressed hand computation. This does not support James Hurley's reported results which indicate nearly half a standard deviation higher mean scores for the computer-integrated sections in Fall 1989 and only slightly higher mean scores for the experimental group in Spring 1990 (Hurley, 1994). However, a possible explanation for the difference in the results is the smaller sample size used in this study which was further subdivided into subgroups by gender. Only students in the small class at the main campus were used in the control group for this study; whereas students in classes of varying sizes were used in the control group for the analysis reported by James Hurley.

In Fall 1993 there were significant differences in achievement on the concept-focused final exam at the 0.055 level between the experimental and the control groups with students in the computer-integrated calculus course having higher mean final exam scores than students in the non-computer-integrated calculus course. It is important to note that the results suggest that female students in the computer-integrated calculus course benefited more from the course than any other subgroup. Although female students in the computer-integrated calculus course had a lower SAT Math mean score than the females in the non-computer-integrated course and the males in both types of courses, the mean exam score of the female students in the computer-integrated calculus course is higher than the females and males in
the non-computer-integrated course. In fact, the mean exam score of the
girl students in the computer-integrated calculus course (122.0) is almost
the same as that of the males in the computer-integrated course (122.8).
Furthermore, female students in the computer-integrated calculus course
tended to have a higher mean score (122.0) than the females in the non-
computer-integrated course (115.2) and male students in the computer-
integrated calculus course tended to have a higher mean score (122.8) than
the males in the non-computer-integrated course (113.2). However, the mean
exam scores of male students (118.2) and female students (118.1) tended to be
the same overall.

In Spring 1994 there were no significant differences in mean exam
scores among subgroups.

Nevertheless, among those students who stayed in the same type of
calculus course for both semesters (either computer-integrated or non-
computer-integrated) students of all subgroups in the computer-integrated
course tended to have higher mean exam scores than students in the non-
computer-integrated course both semesters, Fall 1993 and Spring 1994.
Female students in the computer-integrated course tended to have higher
mean exam scores than female students in the non-computer-integrated
course. Male students in the computer-integrated course tended to have
higher mean exam scores than male students in the non-computer-integrated
course. And all students in the computer-integrated course tended to have
higher mean exam scores than students in the non-computer-integrated
course, although the differences were not significant at the 0.05 level. Furthermore, female students were inclined to have higher mean exam scores than male students, albeit their mean SAT Math score was lower than that of male students.

Overall the results of the Fall 1993 - Spring 1994 analysis of student achievement support the 1989-1990 results in the Hurley report (Hurley, 1994) and others (Bell, 1970; Bitter, 1970/1971; Crocker, 1991/1992; Cunningham, 1991/1992; Holoien, 1970/1971; Ibrahim, 1970; Lang, 1973/1974; Park, 1993; Rice, 1973/1974; Siler, 1990/1991; and Tufte, 1990) that a computer-integrated calculus course is effective in the teaching of calculus concepts and does not interfere with students' learning to apply techniques of calculus. Furthermore, the findings suggest that students in the computer-integrated calculus courses tend to perform better on concept-focused common final exams than students in the non-computer integrated course.

2. Attitudes

Percentage of frequency results higher than 50% of all calculus students responding on the Fall 1993 Attitude Questionnaire included:

Agree or Strongly Agree

83.0% Good math teachers show students lots of different ways to look at the same question.
81.2% My calculus course is helping me understand the basic principles of calculus.

80.6% My calculus class gives me thinking and problem solving skills.

80.0% In the long run, I think taking calculus will help me.

80.0% I find a career in mathematics, science or engineering attractive.

79.4% My calculus class really requires me to think about what I am doing rather than just plugging numbers into formulas.

73.9% My calculus class is preparing me to take higher level math courses.

72.7% My calculus course requires much more thinking than memorization.

72.1% Some people are good at math and some just aren't.

70.3% I like to help others with math problems.

69.1% I am getting a secure foundation in the basics of calculus.

68.5% When I take a math course, I usually get a good grade.

67.3% My calculus class is forcing me to learn a lot of material.

66.1% I enjoy trying to solve a math problem.

65.5% My calculus class gives me a good understanding of what calculus is all about.

64.8% What I've learned in calculus will be useful to me after I've finished the course.

64.2% My advisors in high school encouraged me to take math courses.
61.8% I enjoy doing math problems.
60.6% After I've forgotten all the formulas, I will still be able to use the ideas presented to me in calculus.
60.6% In math you can be creative and discover things by yourself.
56.4% I feel I can apply what I've learned in calculus to real world problems.

Disagree or Strongly Disagree

84.2% Math problems can be done correctly in only one way.
77.6% Understanding of concepts is of little or no value on the tests in my calculus course.
70.3% Most of what is presented to me in calculus is too difficult to grasp.
70.3% Men make better scientists and engineers than women do.
67.9% My calculus course should be covering more material.
64.2% I see no practical use for what I'm learning in my calculus course.
62.4% To solve math problems you have to know the exact procedure for each problem, or you can't do anything.
60% I find what we learn in calculus to be dull, uninteresting and a chore to learn.
50.9% My calculus class is boring.
Chi-square analysis yielded significant differences between genders on the following questions:

A 20: My calculus class is preparing me to take higher level math courses.
All: Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed.
C-I: Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed.
N-CI: There are no significant differences between gender and responses to A20 in non-computer-integrated classes.

A 24: Good math teachers show you the exact way to answer the math questions you'll be tested on.
All: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.
C-I: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.
N-CI: There are no significant differences between gender and responses to A24 in computer-integrated classes.

A 27: My calculus course should be covering more material.

All: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

C-I: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

N-CI: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

A 32: Math problems can be done correctly in only one way.

All: More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed.

C-I and N-CI:

*There were no significant differences in the computer-integrated and non-computer-integrated subgroups.
*Warning: 50% of the cells have expected counts less than 5 in the computer-integrated group and 67% of the cells have expected counts less than 5 in the non-computer-integrated group. Chi-Square may not be a valid test.

A 44: Men make better scientists and engineers than women do.

All: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

C-I: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

N-CI: Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed.

Chi-square analysis yielded significant differences between students in computer-integrated and non-computer-integrated calculus courses on the following questions:

A 21: My calculus course covers too much material too quickly.

F: Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected agreed or disagreed with the statement. More
female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected were neutral.

M: There are no significant differences between the type of course male students are taking and responses to A21.

All: Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected agreed with the statement. More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected disagreed or were neutral.

A 50: My family always encouraged me to take math courses.

F: More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected disagreed.

M: There are no significant differences between the type of course males are taking and responses to A50.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer students in the
computer-integrated course than expected and more students in the non-computer-integrated course than expected disagreed.

The results for C 3, C 8 and C 9 were the same:

C 3: How often do you use a computer at school for numerical computation?
C 8: How often do you use a computer to graph a function or equation?
C 9: How often do you use a computer to do symbolic manipulation?

F: More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time.

M: More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.

All: More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-
computer-integrated course than expected used it less than half the

time.

C 7: How often do you use a calculator to graph a function or equation?

F: There are no significant differences between the type of course females
are taking and responses to C7.

M: More male students in the computer-integrated course than expected
and fewer male students in the non-computer-integrated course than
expected used it half of the time or more. Fewer male students in the
computer-integrated course than expected and more male students in
the non-computer-integrated course than expected used it less than
half the time.

All: More students in the computer-integrated course than expected and
fewer students in the non-computer-integrated course than expected
used it half of the time or more. Fewer students in the computer-
integrated course than expected and more students in the non-
computer-integrated course than expected used it less than half the
time.

The results of the attitude questionnaire and interviews imply that the
majority of students responding in both types of calculus courses enjoy
solving mathematics problems and believe that:

* calculus is useful and can be applied to real world problems,
* calculus requires thinking and understanding of concepts as opposed to rote memorization,
* they can be creative and discover things,
* there is more than one way to solve a problem,
* a career in mathematics, science, or engineering is attractive, and
* gender does not affect a person's potential to be a scientist or an engineer.

This may be surprising to some calculus instructors. As reported by Kim Mc Donald (1987) concerning some mathematicians' opinions:

What's more, those who successfully complete calculus frequently fail to understand the basic concepts of calculus or appreciate its importance, because it is taught in a bland and unimaginative manner, using what one participant termed rote "plug and chug" exercises that have little connection with problems in the real world. (p. A1)

Students in the computer-integrated calculus course tended to use calculators and computers for solving problems on homework and tests and considered them to be useful tools more than students in the non-computer-integrated course.

3. Enrollment in Subsequent Courses

There is a significantly higher mean number of subsequent courses (for which calculus is a direct prerequisite) taken by male students than by female students in the 1989 - 1993 pilot study. No significant differences were found in this study between computer-integrated and non-computer-integrated calculus students. However, when students in calculus classes at all branches
of the university were used as the control group in the analysis referred to by
James Hurley, there were significant differences between the experimental
and control groups. The experimental group had a higher mean number of
subsequent courses (4.9) than the control group (3.5). As James Hurley
reported at the Frontiers in Education Conference in Washington, D. C. in
November 1993:

A set of courses required of sophomore - in some cases junior - majors
in mathematics, science and engineering for which calculus is a
prerequisite was identified. To measure persistence in pursuit of those
majors, for each student enrolled in calculus in 1989 - 90 a count was
made of the number of those courses subsequently taken. . . . students
who were in the experimental calculus sections took significantly (41%)
more of those courses than did students from conventional calculus
sections. (Transparency)

4. Performance in Subsequent Courses

Female mean average grades in subsequent courses for which calculus
is a prerequisite were significantly higher than mean average grades of male
Implications and Recommendations for Mathematics Education in the Future

The results of this study are encouraging. They lend credence to the benefits of integrating computers to make calculus a "pump, not a filter." They sustain the assumption that appropriate use of computer software enhances the teaching and learning of calculus to realize the vision of a more conceptual, intuitive, numerical, symbolic and visual (graphical) calculus. Appropriate and effective use of computer software extends beyond its use for classroom demonstrations. Instructors and students must become skillful in using it as a productive tool for teaching and learning calculus. Based on this researcher's experience integrating the use of computers in her teaching of mathematics at the high school and college level, together with the results of this study, she recommends that calculus instructors keep an open mind toward integrating use of computers as a tool to teach calculus. She admits that it requires more work and more patience than does teaching calculus by traditional methods, particularly the first time one attempts it. She encourages instructors to communicate with those who have experienced success in integrating appropriate use of computers to attend meetings and workshops on calculus reform, and to take the leap and try it. She cautions that instructors of all ages and accomplishments - experienced professors as well as graduate students - must be prepared and supported adequately to take on the extra work and time required to develop necessary skills. Without proper planning, attempts at implementation could result in disaster.
Nevertheless, fear of failure should not deter one's decision to make an honest effort to succeed. She agrees with Thomas Tucker (1987) that three important aspects of using the computer as a resourceful tool should be emphasized:

* to raise as many or more questions as it answers;
* to teach students to think about the reasonableness of their answers; and
* to infuse new mathematics such as the dynamics of functional iteration, stability, three dimensional graphics, optimization, fractals and minimal surfaces.

Tucker (1987) also accentuates the inclusion of contemporary mathematics: "... a little 'live' mathematics in a lean and lively calculus wouldn't hurt, even if it's only a commercial" (p.16).

His comment pertaining to the issue of using computer software to teach students predicts: "We may even end up in the future not only with 'machines who think' [sic] but also with 'students who think'" (p.16).

In the words of some calculus students who participated in confidential interviews concerning the use of the computer as a learning tool for calculus (female in computer-integrated course (FC), female in non-computer-integrated course (FN), male in computer-integrated course (MC)):

FC

... it makes what may be like a black board textbook science more interesting because it's more interactive now and you can manipulate the numbers and change everything by using the computer. It makes it more attractive and more fun for me.
MC
Computer models definitely help - model presentations for graphing of functions in particular. Students should actually be encouraged to go in and try to learn some of the programming for themselves so they can put in their own math functions. If they have to learn to program it, they have to learn it.

MC
Graphing is the best part of it. You can see three dimensional graphs easier. To visualize with a computer some equation you would never be able to graph by hand you can actually learn the theory better.

FN
I would try to see how to use computers with math. I think it should be required for all math classes to have it. If I had a choice I would take the computer-integrated course. Nowadays computers are very important. To learn how to use them with math would be beneficial.

As for the benefit of computer-integrated calculus regarding gender, this study suggests that it tends to aid both genders in achievement.

Moreover, it raises the question: "Is computer-integrated calculus with group activity more beneficial for female students with lower SAT Math scores than for female students with higher SAT Math scores or male students, particularly in the first semester calculus course?"
Suggestions for Future Research

More research is needed:

* to study the effects of a computer-integrated calculus course on female students who tend to have lower SAT Math scores than male students;
* to follow up on differences in the number of subsequent courses taken for which calculus is a prerequisite by all subgroups of students in computer-integrated calculus and students in non-computer-integrated calculus;
* to determine differences in achievement in those courses;
* to determine what content lends itself to computer integration;
* to determine whether class size makes a difference in student attitude and achievement;
* to determine whether class size makes a difference in instructor attitude and its impact on student attitude and achievement;
* to determine if the gender of the instructor impacts attitudes about male/female abilities in mathematics; and
* to investigate appropriate uses of graphing calculators and/or computers in examination settings.
APPENDIX A

COMMON FINAL EXAMS
Final Exam
Math 110
December 16, 1989

Name: ___________________ Section: _______  Seat: _______

Instructions: Total points: 200. Point value of each problem given in parentheses. Work must be clearly shown to receive credit.

Part A Multiple choice questions. CIRCLE the correct answer.

1. (10 pts) Compute \( f'(1) \) if \( f(x) = \sqrt{(3x - 2)^4 + 8} \)
   
   A) 2/3  B) 2  C) 4  D) 4/3  E) None of those

2. (10 pts) Find \( f^{-1}(4) \) if \( f(x) = \frac{3x - 5}{x - 2} \).
   
   A) 4  B) 3/7  C) 7/2  D) 3  E) None of those

3. (10 pts) Find the slope of the tangent line to the curve \((2x - 1)^2 y^2 - zy^3 + 4 = 0\) at the point \((1,2)\).
   
   A) 2  B) -1/2  C) -2  D) 1/2  E) None of those

4. (10) If \( I = \int_{a}^{b} f(x) \, dx \) and \( f(x) \) is the function with the graph as shown, then
   
   A) 0 \leq I \leq 15  
   B) 15 \leq I \leq 30  
   C) 30 \leq I \leq 55  
   D) 55 \leq I \leq 70  
   E) 70 \leq I \leq 100
5. (10 pts) The definite integral giving the arc length of the curve \( y = z^3 \) between 0 and 2 is:

A) \( \int_0^2 \sqrt{1 + z^6} \, dz \)

B) \( \int_0^2 \sqrt{1 + z^{3/2}} \, dz \)

C) \( \int_0^2 \sqrt{1 + z^3} \, dz \)

D) \( \int_0^2 \sqrt{1 + 9z^2} \, dz \)

E) None of those

Part B Give complete answers.

6. (15 pts) Let \( f(z) = \begin{cases} (\sin z)/z, & \text{if } z > 0; \\ z + 1, & \text{if } z \leq 0 \end{cases} \)

a) Find \( \lim_{z \to 0^+} f(z) \)

b) Find \( \lim_{z \to 0^-} f(z) \)

c) Is \( f(z) \) continuous at \( z = 0 \)? Explain your answer.

7. (10 pts) \( \frac{d}{dz} \left( \frac{2 - \cos z}{2 + \cos z} \right) = ? \)

8. (15 pts) The gravitational acceleration \( g \) at the earth’s surface is constant, but varies with the distance \( r \) from the earth’s center according to the formula \( g = \frac{GM}{r^2} \), where \( G \) is the universal gravitational constant and \( M \) is the constant mass of the earth.

a) Find \( dg \) in terms of \( dr, r, G, \) and \( M \)

b) Express the percent change in \( g \) in terms of the percent change in \( r \)
9. (30 pts) Given that 
\[ f(x) = \frac{x^2 + z - 2}{z^2}, \quad f'(x) = \frac{4 - z}{z^3}, \quad f''(x) = \frac{2(z - 6)}{z^4} \]

a) Determine vertical and horizontal asymptotes and zeros.

b) Determine intervals of increase and decrease, critical points and extreme values.

c) Determine concavity and inflection points.

d) Sketch the graph.
10. (5 pts) If the graph of $f$ is as shown, then is $f$ differentiable at $x = c$? Why or why not?

11. (10 pts) The region in the first quadrant bounded by the curve $y = 2x^3$ and the line $y = 8x$ is revolved around the $x$-axis. Express the volume as a definite integral (but do not attempt to evaluate the integral).

12. (5 pts) Express as a single definite integral:

\[ \int_{1}^{3} (x^5 + 1)^5 \, dx + \int_{-2}^{1} (x^5 + 1)^5 \, dx = \]

13. (15 pts) The area of a square is decreasing at a rate of 5 cm$^2$/min. Find the rate of change of the length of a side when the area is 100 cm$^2$. 

175
14. (10 pts) \[
\frac{d}{dx} \left( \int_{x^2}^{2} \sin t^3 \, dt \right) =?
\]

15. (15 pts) \[
\int_{\pi/3}^{\pi} \frac{\sin x}{\cos^2 x} \, dx =?
\]

16. (20 pts) Let \( f(z) = (z - 2)^2(3 - z) \), \( 2 \leq z \leq 4 \).
   a) Find the critical points
   b) Find the absolute maximum and minimum values of \( f(z) \)
17. (Bonus 10 pts) Find $f$ and $a \in [0, \pi)$ satisfying $\int_a^\pi f(t)\,dt = \tan z - 1$.

18. (Bonus 10 pts) A person takes a 10 mg dose of medicine. Its rate of breakdown by the body is approximated by $\frac{dy}{dt} = \frac{-1}{8}(1 + 2t)$, where $t$ is the number of hours after the medicine was taken. (a) Find the formula for the number of mg $y$ of the tablet left after $t$ hours. (b) If the patient's doctor wants at least 1 mg of the medication to be in the patient's system when the next dose is taken, when should the next dose be prescribed?
Math 111 Final Exam

May 10, 1990

Name: ____________________________

The value of each question is indicated in the left margin. Budget your time accordingly: approximately five minutes for each 10 points. That will leave time to check your work or to attempt the two bonus questions.

Show all work clearly in the space provided. For full credit, solution methods must be logical and understandable, and must involve only techniques and results developed in this course or in Math 110 or 120. Answers must be clearly labeled, must give the information asked for in the statement of the problem, and must follow logically from the preceding work. Work done outside the space provided can be considered only if directions to it are clearly and prominently given within the provided workspace.

5 1. (a) Evaluate \( \int_0^1 \frac{x - 1}{x + 1} \, dx \).

(b) Find \( f'''(x) \) if \( f(x) = xe^x \).

10 2. A colony of bacteria has initial mass \( 1.50 \times 10^{-9} \) gm. After an hour, the mass is \( 2.12 \times 10^{-9} \) gm. When will the mass be double its initial size, if the growth rate is exponential?

10 3. Find \( \lim_{x \to 0} \frac{\sin x - x}{x^3} \).

10 4. (a) Evaluate \( \int \tan^{-1}x \, dx \).

(b) Evaluate \( \int \frac{dx}{\sqrt{x^2 + 4}} \).

15 5. (a) Evaluate \( \int \frac{(x^2 + 7)dx}{(x - 1)(x^2 + 2x + 5)} \).

(b) Evaluate \( \int_0^1 \frac{dx}{\sqrt{1 - x^2}} \).

5 6. (a) Give the rectangular coordinate equation for the curve whose polar equation is \( r = 2/(1 - \cos \theta) \).

(b) Graph the two curves \( r = 1 \) and \( r = 1 + \cos \theta \) on the same
coordinate system.

7. (a) Determine whether the sequence \((a_n)\) converges, if
\[
a_n = \frac{\tan^{-1} n}{\sqrt{n}}.
\]
If the sequence is convergent, find its limit.

7. (b) Determine whether the series \(\sum_{n=1}^{\infty} \frac{3^n - 1}{8 \cdot 2^n}\) is convergent, and if it is find its sum.

8. (a) Show that the series \(\sum_{n=1}^{\infty} \frac{1}{n^2} \sin\left(\frac{1}{n^2}\right)\) is convergent.

8. (b) Determine whether \(\sum_{n=1}^{\infty} \frac{(-1)^n n^2}{2 \cdot 5 \cdot 8 \cdot \cdots \cdot (3n-1)}\) converges. If so, is the convergence absolute?

9. (a) Find the fourth-degree Taylor polynomial of \(f(x) = \sqrt{x}\) about \(a = 1\).

9. (b) Find the interval of convergence of \(\sum_{n=1}^{\infty} \frac{nx^n}{n+1}\).

9. (c) Find the Taylor series of \(\cosh x = \frac{e^x + e^{-x}}{2}\) about \(a = 0\).

10. (a) Find a unit vector perpendicular to \(v = (1, 5, -4)\).

10. (b) Find the vector obtained by projecting \(x = -i + 2j + k\) perpendicularly onto \(v = 3i + 4k\). That is, find the component of \(x\) in the direction of \(v\).

11. (a) Find the equation of the plane consisting of all points \(P(x, y, z)\) such that \(PQ\) is perpendicular to \(n\), where \(Q\) is the point \((2, -1, 3)\) and \(n = i - 2j + k\).
(b) Let \( L \) be the line through \( P(-1, 2, 3) \) and \( Q(2, 0, 1) \). Find a set of parametric equations for \( L \).

(c) Suppose that \( L_1 \) and \( L_2 \) have respective parametric equations
\[
\begin{align*}
    x &= 3 - t, \quad y = 7 + 2t, \quad z = 1 + 3t, \\
    x &= 9 + 4s, \quad y = 4 + s, \quad z = 3 + 8s.
\end{align*}
\]
Show that \( L_1 \) and \( L_2 \) intersect, and find their common point.

**Bonus Questions** (partial credit possible):

12. (a) Find \( a \) and \( b \) so that \( f \) is differentiable at \( x = 0 \) if
\[
f(x) = \begin{cases} 
    b(x - 1)^2 & \text{for } x \geq 0 \\
    e^x + ax & \text{for } x < 0
\end{cases}
\]

(b) If the vectors \( x \) and \( y \) have the same length, then show that \( x + y \) is perpendicular to \( x - y \).

13. The change in the reaction rate of gases is described by the equation
\[
\frac{dk}{dT} = \frac{E_a}{R} \frac{k}{T^2},
\]
where \( k \) is the rate of reaction, \( T \) is the Kelvin temperature, \( R \) is the universal gas constant, and \( E_a \) is a constant called the *activation energy* of the given reaction. If \( k = k_1 \) when \( T = T_1 \), then find the formula for \( k \) as a function of \( T \). Here, \( k \) is known to be nonnegative.
Before starting to work, make sure that you have a complete exam: 8 numbered pages stapled to this page.

The point value of each question is indicated before its statement. Budget your time accordingly: about five minutes for each ten points. That will leave time to check your work or to attempt the bonus question. The maximum score for averaging purposes is 200, although up to 220 points can be earned. The absolute deadline for handing in the exam is 5:30 PM.

Do not write anything on this cover page below the following solid line.
Show all work clearly in the space provided. For full credit, solution methods must be logical and understandable, and must involve only techniques and results developed thus far in this course. Answers must be clearly labeled, must give the information asked for, and must follow logically from the the preceding work. Be sure to read the question carefully! Work done outside the space provided can be considered only if clear and explicit directions to it are given within the workspace for that question. Mark out (or fully erase) any work that you do not want to be graded.

1. The function $h$ is defined by

$$h(x) = \begin{cases} 
  x^2 + 5x - 3 & \text{for } x \leq 1 \\
  x^2 + 2x - 3 & \text{for } x > 1 \\
  2x^2 - 3x + 1 & \text{for } x > 1
\end{cases}$$

(a) (5 points) Find $\lim_{x \to 1^-} h(x)$ and $\lim_{x \to 1^+} h(x)$

(b) (5 points) Does $\lim_{x \to 1} h(x)$ exist? Why or why not?

(c) (5 points) Is $h$ continuous at $x = 1$? Why or why not?

(d) (5 points) Is $h$ differentiable at $x = 1$? Why or why not?

(e) (5 points) At which numbers $x$ is $h$ necessarily continuous? Why?
2. Let \( f \) be a function and \( c \) a fixed number in the domain of \( f \).

(a) (10 points) Give a limit definition of \( f'(c) \).

(b) (15 points) Use your definition in (a) to compute \( f'(2) \) if \( f(x) = x^2 + x + 1 \).

3. (15 points) Suppose that the equation \( y^2 + 2xy + x^3 = 9 \) defines \( y \) as a differentiable function of \( x \) near the point \((1, 2)\). Find \( \frac{dy}{dx} \) at \((1, 2)\).
4. (15 points) A spherical balloon has volume \(36\pi\), which changes to \(36.037\pi\) when the temperature rises. Use the tangent approximation to estimate the corresponding change in the radius of the balloon. (The volume of a ball of radius \(r\) is \(\frac{4}{3}\pi r^3\)).

5. (a) (10 points) If \(y = \sin^2(x^3)\), then give the formula for \(\frac{dy}{dx}\).

(b) (10 points) If \(f(x) = (x + \sqrt{x^3 + 1})^4\) then find \(f'(2)\).

6. A manager of a 100-seat theater can fill all the seats for a weekend movie at an admission price of \$3.00. For every extra 5 cents she charges per ticket, she loses one customer. She wants to maximize her total revenue, which is the product of the number of tickets sold times the price per ticket. Let \(R(x)\) be her total revenue at a ticket price of \(300 + 5x\) cents per ticket.

(a) (5 points) \(R(x) = \) _____________________________

(b) (5 points) A reasonable range of \(x\)-values is: \(____ \leq x \leq ____\).

(c) (15 points) Find the ticket price that will maximize revenue over the interval in (b) (use calculus). What is the maximum revenue?
7. For each question, print the block capital letter that corresponds to your choice of answer.

(a) (2 points) The graph of \( f(x) = \frac{x^3}{x^2 - 1} \) is shown above. From the graph, how many critical points do there appear to be?

(A): 0  (B): 1  (C): 2  (D): 3  (E): 4

(b) (2 points) A function has the following graph.

From the graph, the absolute maximum on \([-2, 2]\) appears to be

(A): 0  (B): 1  (C): 2  (D): 3  (E): 4.6

Answer: _______
(c) (8 points) Based on the graph of $f$ above, mark each statement true (T) or false (F).

(A) $f$ is increasing and concave down on $(-2, 0)$  
(B) $(3, 0)$ is a point of inflection  
(C) $f$ has a local maximum at $x = 1$  
(D) $x = 3$ is a local minimum point

(d)  
The graph of $f(x) = \frac{x^2}{x^2 - 5}$ is shown above. Mark each statement true (T) or false (F).

(A) $f$ is concave up on $(\sqrt{5}, 5)$  
(B) $f$ is decreasing on $(-\sqrt{5}, \sqrt{5})$  
(C) $\lim_{x \to \infty} f(x) = 1$  
(D) $f$ is one-to-one on $(-5, -\sqrt{5})$
Which expression represents the area bounded by $f$ and $g$ in the above picture?

(A) $\int_{-3}^{3} (g(x) - f(x)) \, dx$.

(B) $\int_{-3}^{3} (g(x) - f(x)) \, dx + \int_{0}^{3} (f(x) - g(x)) \, dx$.

(C) $\int_{-3}^{0} (f(x) - g(x)) \, dx - \int_{0}^{3} (g(x) - f(x)) \, dx$.

(D) $\int_{-3}^{3} (f(x) - g(x)) \, dx$

(E) $\int_{-3}^{0} (f(x) - g(x)) \, dx + \int_{0}^{3} (g(x) - f(x)) \, dx$

Answer: _____

8. Evaluate the following:

(a) (10 points) $\int_{-1}^{2} (5t^2 - 2t) \, dt$

(b) (10 points) $\int_{0}^{\pi/4} \cos 2x \sqrt{1 + 3 \sin 2x} \, dx$
9. Let \( f(x) = x^2 + 2x + 2 \). Let \( P = \{-2, 1, 4\} \) be a partition of the interval \([-2, 4]\), where \( x_0 = -2, x_1 = 1, x_2 = 2, x_3 = 4 \). Let \( z_1 = 0, z_2 = 2, z_3 = 3 \).

(a) (10 points) Find the Riemann sum that corresponds to the above partition and points.

(b) (10 points) Sketch the graph of the function \( y = f(x) \) over \([-2, 4]\), and draw in the rectangles whose areas the Riemann sum evaluates.
Bonus Questions. Attempt these questions only after having completed and checked over all the earlier questions. (10 points maximum for each, partial credit possible).

10. (10 points) Consider $g(x) = x^3 + x + 1$

(a) Show that for some $c$ between $-1$ and 0 $g(c) = 0$.

(b) Show that $g$ has exactly one zero $c$.

11. (10 points) If $f$ is continuous on $[a, +\infty)$ and $\int_a^x f(t)dt = x^2 - 3$ for all $x \in (a, +\infty)$ then find a formula for $f$ and the value of $a$. 
Math 116 Final Examination

May 16, 1994

Name: ____________________________________________________________

Social Security Number: ___________________ Section: __________________

Instructor’s Name: __________________________________________________

Before starting to work, make sure that you have a complete exam: 11 numbered pages stapled to this page.

The point value of each question is indicated before its statement. Budget your time accordingly: about five minutes for each ten points. That will leave time to check your work or to attempt the bonus question. The maximum score for averaging purposes is 200, although up to 220 points can be earned. The absolute deadline for handing in the exam is 5:30 PM.

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Subtotal ______ Subtotal ______ Bonus: ______

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Subtotal ______

TOTAL SCORE: ______
Show all work clearly in the space provided. For full credit, solution methods must be logical and understandable, and must involve only techniques and results developed thus far in this course, Math 115, or Math 120. Answers must be clearly labeled, must give the information asked for, and must follow logically from the preceding work. Be sure to read the question carefully! Work done outside the space provided can be considered only if clear and explicit directions to it are given within the workspace for that question. Mark out (or fully erase) any work that you do not want to be graded.

Part 1.

1. Multiple Choice (5 points each). In the space provided, print the block capital letter of the choice that correctly completes each statement.

   (i) given the graph of \( f \),

   ![Graph of f](image)

   let \( g(x) = \int_{0}^{x} f(t)dt \). Which of the following is the graph of \( g \)?

   ![Graphs A and B](image)

   ![Graphs C and D](image)

   Answer:____
(ii) The derivative of \( f(x) = \ln x^2 + (\ln x)^2 \) is

(A) \( 2 \ln x + \frac{1}{x^2} \)  
(B) \( \frac{2(1 + \ln x)}{x} \)  
(C) \( \frac{1}{x^2} + \frac{2 \ln x}{x} \)

(D) \( \frac{2 + \ln x}{x} \)  
(E) \( 4 \ln x \)

Answer: ___

(iii) The derivative of \( f(x) = 2^{3x+1} \) is

(A) \( (3x + 1)2^{3x} \)  
(B) \( (3x + 1)2^{3x} \ln 2 \)  
(C) \( 3 \ln 2 \cdot 2^{3x+1} \)

(D) \( 2^{3x+1} \ln 2 \)  
(E) \( 3 \cdot 2^{3x+1} \)

Answer: ___

(iv) \( \int_1^e \frac{(\ln x)^3}{x} \, dx = \)

(A) 0  
(B) \( \frac{1}{4} \)  
(C) \( \frac{x^4}{4} - \frac{1}{4} \)  
(D) 1  
(E) \( \frac{3}{4} \)

Answer: ___

(v) Which expression gives the area of the shaded region?

(A) \( \int_0^3 (x^2 + x - 2) \, dx \)

(B) \( \int_0^1 (x^2 + 1) \, dx + \int_1^3 (-x + 3) \, dx \)

(C) \( \int_0^3 (-x^2 - x + 2) \, dx \)

(D) \( \int_0^1 (x^2 - 1) \, dx - \int_1^3 (-x + 3) \, dx \)

(E) \( \int_0^2 (x^2 - x - 2) \, dx \)

Answer: ___
2. (15 points) Find the volume of the solid generated by revolving the following region about the $z$-axis: between the $z$-axis, the $y$-axis, the graph of $y = e^x$, and the line $x = 1$.

3. (10 points) One of the main contaminants released at the Chernobyl nuclear accident in 1986 was the carcinogen strontium-90, whose half life is 28 years. What per cent of the strontium-90 released 8 years ago at Chernobyl is still undecayed in 1994?
Part 2.

4. **Multiple Choice** (5 points each). In the space provided, print the block capital letter of the choice that correctly completes each statement.

(i) If \(f(x) = \arcsin 2x\), then \(f'(0) = \)

\[
\begin{align*}
(A) \frac{\sqrt{2}}{2} & \quad (B) \frac{2}{\sqrt{3}} & \quad (C) 0 & \quad (D) \frac{\pi}{2} & \quad (E) 2
\end{align*}
\]

Answer: ____

(ii) \(\lim_{x \to 1} \frac{\ln x}{x^2 - 1} = \)

\[
\begin{align*}
(A) 0 & \quad (B) \frac{1}{2} & \quad (C) 1 & \quad (D) 2 & \quad (E) -\infty
\end{align*}
\]

Answer: ____

(iii) The slope of the tangent line at \(t = 3\) to the parametrically defined curve \(x = t^2 - 1, y = 2 + 3t\) for \(t \in [0, 5]\) is

\[
\begin{align*}
(A) \frac{1}{2} & \quad (B) 2 & \quad (C) 3 & \quad (D) \frac{1}{3} & \quad (E) \frac{1}{3}
\end{align*}
\]

Answer: ____
(iv) The graph of \( r = 1 - \cos \theta \) is given by which of the following?

(A) ![Image](image1)

(B) ![Image](image2)

(C) ![Image](image3)

(D) ![Image](image4)

(E) ![Image](image5)

Answer: ___
5. (15 points) Evaluate \( \int_{-1}^{3} (x + 2)e^x \, dx \)

6. (15 points) Evaluate \( \int_{-2}^{0} \frac{4}{x^2 - 4x + 3} \, dx \)
Part 3

7a. **True or False** (2 points each - 18 points total). In the blank provided, mark each statement true (T) or false (F).

(i) The sequence \((a_1, a_2, \ldots, a_n, \ldots)\) converges, if \(a_n = \frac{2n^2 + 3n - 1}{4n^3 + 6n^2 - n}\). ___

(ii) The sequence \(a = (-1, -\frac{3}{2}, -\frac{9}{4}, -\frac{27}{8}, -\frac{81}{16}, \ldots, -\frac{3^{n-1}}{2^{n-1}}, \ldots)\) is bounded. ___

(iii) \(\sum_{n=1}^{\infty} (-1)^n \frac{n}{n+1}\) is convergent. ___

(iv) \(\sum_{n=1}^{\infty} \frac{1}{e^n}\) is convergent. ___

(v) \(\sum_{n=1}^{\infty} (-1)^n\) is convergent. ___

(vi) \(\sum_{n=1}^{\infty} \frac{1}{3\sqrt{n}}\) is convergent. ___

(vii) If \(\lim_{n \to \infty} a_n = 0\) then \(\sum_{n=1}^{\infty} a_n\) converges. ___

(viii) If \(\sum_{n=1}^{\infty} a_n\) converges but \(\sum_{n=1}^{\infty} b_n\) diverges, then \(\sum_{n=1}^{\infty} (a_n + b_n)\) must diverge. ___

(ix) For the series of positive terms \(\sum_{n=1}^{\infty} a_n\) and \(\sum_{n=1}^{\infty} b_n\), if \(\sum_{n=1}^{\infty} b_n\) converges and \(\lim_{n \to \infty} \frac{a_n}{b_n} = 1\) then \(\sum_{n=1}^{\infty} a_n\) must converge. ___

7b. **Multiple Choice** (2 points). In the space provided, print the block capital letter of the choice that correctly completes the following statement.

The geometric series \(2 - 2\frac{\sqrt{2}}{5} + \frac{4}{25} - \frac{4\sqrt{2}}{125} + \frac{8}{625} + \cdots\)

(A) converges to \(\frac{10}{5-\sqrt{2}}\).  (B) converges to \(\frac{2}{5-\sqrt{2}}\).  (C) converges to \(\frac{10}{5+\sqrt{2}}\).

(D) converges to \(\frac{2}{5+\sqrt{2}}\).  (E) diverges.

Answer: ___
8. (15 points) Find the area of the region inside the cardioid $r = 1 - \sin \theta$.

9. (15 points) Determine the interval of convergence of the power series

$$
\sum_{n=0}^{\infty} \frac{3^n(x - 2)^n}{n4^n}
$$

Where is the convergence absolute?
10. (15 points) Find the Taylor series about $x = 0$ for $f(x) = \frac{1}{(1 - x)^3}$.

11. (a) (5 points) Find the angle between $v = 6i + 6k$ and $w = 5j + 5k$.

(b) (5 points) Let $a = i - j - k$, $b = 3i - 2k$, $c = j + k$.

(i) Find $a - 3b - c$  
(ii) Find $\frac{a}{|a|} + \frac{b}{|b|}$  
(iii) Find $\frac{a - b}{|c|}$
(c) (5 points) Give a normal vector to the plane whose scalar equation is 
\[3x + 2y - 7z = 18.\]

(d) (5 points) Find a vector equation of the line through \((-1, 4, 1)\) and \((2, 0, 3)\).

(e) (5 points) For \(x = (1, 3)\) and \(v = (2, 4)\), find the component of \(x\) in the direction of \(v\).

(f) (5 points) Find the point of intersection of the lines \(x = t(1, 0, 3) + (5, 1, 13)\) and \(x = s(1, 2, 3) + (0, -1, -2)\), if it exists.

(g) (5 points) Find a normal vector to the plane determined by the lines \(x = (5, 1, 13) + t(1, 0, 3)\) and \(x = (0, -1, -2) + s(1, 2, 3)\).
Bonus Questions. Attempt these questions only after having completed and checked over all the earlier questions. (10 points maximum for each, partial credit possible).

12. (a) Suppose that \( f(0) = 1 \), and \( f(x) = (e^x - 1)/x \) for \( x \neq 0 \). Find the Taylor series for \( f \) about 0, and explain why you know that it converges to \( f(x) \) for every \( x \). Use term-by-term differentiation to show that \( \sum_{n=1}^{\infty} \frac{n}{(n+1)!} \) converges to 1.

(b) If \( f \) is a continuous function that satisfies \( f(x) = 1 + \int_0^x [f(t)^2 + 1] \, dt \) on \( [0, \frac{1}{2}] \), then find a formula for \( f \) in terms of elementary functions.
APPENDIX B

ATTITUDE QUESTIONNAIRE
December, 1993

Assessment Survey for Math 115 and Math 116

We need your help in assessing the effectiveness of our first-year calculus instruction. The attached anonymous survey was developed by the University's Institute for Social Inquiry/Roper Center and Duke University. While in some of your other courses you may have completed a survey about your instructor, this one is designed to provide a more in-depth appraisal of the course as a whole, the impressions it has left you with, and your reaction to it. This information will be used to help the UConn Math Department provide the best possible quality of instruction to future students, including you if you continue in the calculus sequence. Please take the time to give us your input by completing the survey and bringing it to the last class meeting for collection.

There are no right or wrong answers: we just want to know your attitude about calculus now that you have had a chance to experience at least a full semester.

Before turning this page, please complete the following three questions by checking the blank that follows the appropriate category.

1. **Check course:** Math 115Q ____ Math 115V ____ Math 116Q ____ Math 116V ____

2. **Your gender:** Male ____ Female ____

3. **Your Citizenship:** American ____ Canadian ____ Other, but U. S. or Canadian Permanent Resident ____ Other, Non-resident alien ____

If you are an American citizen or permanent resident, also please complete the following question:

4. **Your ethnic identification:** Asian/Pacific Islander ____ Black ____ Hispanic ____

   Native American ____ Puerto Rican ____ White ____
ASSESSMENT SURVEY FOR CALCULUS STUDENTS

DIRECTIONS: THE INFORMATION GATHERED THROUGH THIS SURVEY WILL BE USED TO MAKE IMPROVEMENTS IN THE WAY CALCULUS IS TAUGHT. ALL ANSWERS WILL BE KEPT CONFIDENTIAL; YOUR INSTRUCTOR WILL NOT KNOW HOW YOU RESPONDED. THERE ARE NO RIGHT OR WRONG ANSWERS; JUST TELL US HOW YOU FEEL.

FOR EACH QUESTION PLEASE CIRCLE THE NUMBER THAT CORRESPONDS TO THE ANSWER THAT BEST DESCRIBES YOUR FEELINGS.

A. For the following statements, please:
   Circle 1 if you strongly agree.
   Circle 2 if you somewhat agree.
   Circle 3 if you are neutral.
   Circle 4 if you somewhat disagree.
   Circle 5 if you strongly disagree.

1. The best way to do well in calculus is to memorize all the formulas.  
2. I've applied what I've learned in calculus to my work in non-math courses.  
3. What I've learned in calculus will be useful to me after I've finished the course.  
4. My advisors in high school encouraged me to take math courses.  
5. Just about everything important about math is already known by mathematicians.  
6. Good math teachers show students lots of different ways to look at the same question.  
7. My calculus class is too theoretical and not practical enough.  
8. After I've forgotten all the formulas, I will still be able to use the ideas presented to me in calculus.  
9. I feel that I can apply what I've learned in calculus to real world problems.  
10. Some people are good at math and some just aren't.  
11. To solve math problems you have to know the exact procedure for each problem, or you can't do anything.  
12. My calculus class really requires me to think about what I am doing rather than just plugging numbers into formulas.  
13. I find what we learn in calculus to be dull, uninteresting and a chore to learn.
14. In math you can be creative and discover things by yourself.

15. My calculus class is boring.

16. My calculus class gives me thinking and problem solving skills.

17. I enjoy doing math problems.

18. Most of what is presented to me in calculus is too difficult to grasp.

19. My calculus course requires much more thinking than memorization.

20. My calculus class is preparing me to take higher level math courses.

21. My calculus course covers too much material too quickly.

22. I'm glad I'm taking calculus.

23. In my calculus course I think I really understand and am not just mimicking techniques.

24. Good math teachers show you the exact way to answer the math questions you'll be tested on.

25. My calculus class helps me see how math is useful.

26. In math, an answer is either right or it is wrong.

27. My calculus course should be covering more material.

28. Most of the work in my calculus class is pretty easy.

29. I am getting a secure foundation in the basics of calculus.

30. In my calculus course there is not enough time to fully grasp and understand all the important concepts.

31. My calculus class gives me a good understanding of what calculus is all about.

32. Math problems can be done correctly in only one way.
34. I see no practical use for what I’m learning in my calculus course.

35. My calculus course is helping me understand the basic principles of calculus.

36. In the long run, I think taking calculus will help me.

37. My calculus class is forcing me to learn a lot of material.

38. On the whole, I'd say my calculus class is pretty interesting.

39. In my calculus class I got to apply calculus to real world problems.

40. It is important to know math to get a good job.

41. If I have my choice, I will not take any more math.

42. I enjoy trying to solve a math problem.

43. I like to help others with math problems.

44. Men make better scientists and engineers than women do.

45. I don't like to ask questions in math class.

46. I would like to have a job that uses a lot of math.

47. I find a career in mathematics, science or engineering attractive.

48. Anyone who works hard can do well in math courses.

49. When I take a math course, I usually get a good grade.

50. My family always encouraged me to take math courses.

51. I probably will take this course again in college.

B. When you have trouble with a math problem, what do you usually do?
Circle the number of the answer that best describes what you do.

1. Try it another way
2. Ask a friend for help
3. Ask the teacher for help
4. Come back to it later
5. Ask a friend for the answer
6. Give up
7. Write down any answer, even if I don't think it's the right one
C. How often do you do the following things in this course? Circle the number of the answer that best describes what you do.

Circle 1 if you do it all or almost all the time.
Circle 2 if you do it more than half the time.
Circle 3 if you do it about half the time.
Circle 4 if you do it less than half the time.
Circle 5 if you do it rarely or never.

1. Use a calculator for numerical computation.

2. Use a computer at home for numerical computation.

3. Use a computer at school for numerical computation.

4. Draw a graph by hand.

5. Do a numerical computation by hand.

6. Do a symbolic computation by hand.

7. Use a calculator to graph a function or equation.

8. Use a computer to graph a function or equation.

9. Use a computer to do a symbolic computation.

10. Use calculus to analyze problems from other subjects.

D. BEFORE taking this course, how many additional math courses had you planned to take? Circle the number of the answer that best describes your plans.

1. One additional course.
2. Two or three additional courses.
3. Four or five additional courses.
4. More than five additional courses.
5. Not sure.

E. AFTER taking this course, how many additional math courses are you planning to take? Circle the number of the answer that best describes your plans.

1. One additional course.
2. Two or three additional courses.
3. Four or five additional courses.
4. More than five additional courses.
5. Not sure.

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE. PLEASE USE THIS SPACE FOR ANY COMMENTS YOU HAVE.
APPENDIX C

PROGRAM CODE EXAMPLE
REM Program InMIDPT to approximate \( \ln b \) by midpoint rule

def \( f(x) = \frac{1}{x} \)

INPUT PROMPT "Compute \( \ln b \) for \( b = ? \)": \( b \)
INPUT PROMPT "Maximum number of subintervals ?": \( U \)
INPUT PROMPT "Successive approximations how close to stop ?": \( E \)
print
print "n", \( \text{Mn}(f)" \)

let \( a = 1 \)
let \( n = 10 \) ! Start with 10 subintervals
let \( T = 100 \)
do while \( n <= U \) and abs(S - T) >= \( E \)
    let \( h = (b - a)/n \)
    for \( j = 1 \) to \( n \)
        let \( mx = a + h/2 + (j - 1)*h \) ! Midpoint of \( j \)-th subinterval
        let \( M = M + f(mx) \) ! Midpoint rule running sum
    next \( j \)
    let \( Mn = M*h \) ! Midpoint approximation

print \( n, Mn \)

let \( n = 2\times n \) ! Double number of subintervals
let \( S = T \)
let \( T = Mn \)
let \( M = 0 \) ! Reset running sum to 0
loop
end
APPENDIX D

CHI-SQUARE TABLES FOR SIGNIFICANT DIFFERENCES IN ATTITUDE SURVEY BY GENDER
Significant Results By Gender

Questionnaire instructions for Part A were as follows:

A. For the following statements, please:
   
   Circle 1 if you strongly agree.
   Circle 2 if you somewhat agree.
   Circle 3 if you are neutral.
   Circle 4 if you somewhat disagree.
   Circle 5 if you strongly disagree.

Responses with significant differences at the $\alpha = .05$ level Chi-Square Analysis:

A20: "My calculus class is preparing me to take higher level math courses."

<table>
<thead>
<tr>
<th>Null Hypothesis: There are no differences between gender and responses to A20.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Female Observed</td>
</tr>
<tr>
<td>Female Expected</td>
</tr>
<tr>
<td>Male Observed</td>
</tr>
<tr>
<td>Male Expected</td>
</tr>
</tbody>
</table>
Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed. The Chi-Square value of 12.245 with 2 degrees of freedom has probability $0.002 < 0.05$. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A20.

**Computer-Integrated**

Null Hypothesis: There are no differences between gender and responses to A20 in computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>21</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Female Expected</td>
<td>28.247</td>
<td>5.172</td>
<td>3.5806</td>
</tr>
<tr>
<td>Male Observed</td>
<td>50</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Male Expected</td>
<td>42.753</td>
<td>7.828</td>
<td>5.4194</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement. More females than expected and fewer males than expected were neutral or disagreed. The Chi-Square value of 13.216 with 2 degrees of freedom has probability $0.001 < 0.05$. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A20 in computer-integrated classes.
Non-Computer-Integrated

Null Hypothesis: There are no differences between gender and responses to A20 in non-computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>18</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>Female Expected</td>
<td>20</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Male Observed</td>
<td>32</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Male Expected</td>
<td>30</td>
<td>9</td>
<td>3</td>
</tr>
</tbody>
</table>

*The Chi-Square value of 1.444 with 2 degrees of freedom has probability 0.486 > 0.05. Therefore, we must accept the null hypothesis and conclude that there are no significant differences between gender and responses to A20 in non-computer-integrated classes.

*Warning: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.
A24: "Good math teachers show you the exact way to answer the math questions you'll be tested on."

Null Hypothesis: There are no differences between gender and responses to A24

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>23</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Female Expected</td>
<td>20.337</td>
<td>15.153</td>
<td>29.509</td>
</tr>
<tr>
<td>Male Observed</td>
<td>28</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Male Expected</td>
<td>30.663</td>
<td>22.847</td>
<td>44.491</td>
</tr>
</tbody>
</table>

More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 7.333 with 2 degrees of freedom has probability 0.026 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A24.
Computer-Integrated

Null Hypothesis: There are no differences between gender and responses to A24 in computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>14</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Female Expected</td>
<td>11.538</td>
<td>8.3548</td>
<td>17.108</td>
</tr>
<tr>
<td>Male Observed</td>
<td>15</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>Male Expected</td>
<td>17.462</td>
<td>12.645</td>
<td>25.892</td>
</tr>
</tbody>
</table>

More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 7.385 with 2 degrees of freedom has probability 0.025 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A24 in computer-integrated classes.

Non-Computer-Integrated

Null Hypothesis: There are no differences between gender and responses to A24 in non-computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>9</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Female Expected</td>
<td>8.8</td>
<td>6.8</td>
<td>12.4</td>
</tr>
<tr>
<td>Male Observed</td>
<td>13</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Male Expected</td>
<td>13.2</td>
<td>10.2</td>
<td>18.6</td>
</tr>
</tbody>
</table>
The Chi-Square value of 1.146 with 2 degrees of freedom has probability 0.564 > 0.05. Therefore, we must accept the null hypothesis and conclude that there are no significant differences between gender and responses to A24 in computer-integrated classes.

A27: "My calculus course should be covering more material."

All

Null Hypothesis: There are no differences between gender and responses to A27.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>4</td>
<td>6</td>
<td>55</td>
</tr>
<tr>
<td>Female Expected</td>
<td>7.5767</td>
<td>13.558</td>
<td>43.865</td>
</tr>
<tr>
<td>Male Observed</td>
<td>15</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Male Expected</td>
<td>11.423</td>
<td>20.442</td>
<td>66.135</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 14.518 with 2 degrees of freedom has probability 0.001 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A27.

Computer-Integrated

Null Hypothesis: There are no differences between gender and responses to A27 in computer-integrated classes.
<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>2</td>
<td>4</td>
<td>31</td>
</tr>
<tr>
<td>Female Expected</td>
<td>3.9785</td>
<td>8.3548</td>
<td>24.667</td>
</tr>
<tr>
<td>Male Observed</td>
<td>8</td>
<td>17</td>
<td>31</td>
</tr>
<tr>
<td>Male Expected</td>
<td>6.0215</td>
<td>12.645</td>
<td>37.333</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 8.104 with 2 degrees of freedom has probability 0.017 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A27 in computer-integrated classes.

**Non-Computer-Integrated**

Null Hypothesis: There are no differences between gender and responses to A27 in non-computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>2</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Female Expected</td>
<td>3.6</td>
<td>5.2</td>
<td>19.2</td>
</tr>
<tr>
<td>Male Observed</td>
<td>7</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>Male Expected</td>
<td>5.4</td>
<td>7.8</td>
<td>28.8</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 6.467 with 2 degrees of freedom has probability 0.039 < 0.05. Therefore, we must reject the null hypothesis.
and conclude that there are significant differences between gender and responses to A27 in non-computer-integrated classes.

A32: "Math problems can be done correctly in only one way."

Null Hypothesis: There are no differences between gender and responses to A32.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>5</td>
<td>1</td>
<td>59</td>
</tr>
<tr>
<td>Female Expected</td>
<td>3.9877</td>
<td>6.3804</td>
<td>54.632</td>
</tr>
<tr>
<td>Male Observed</td>
<td>5</td>
<td>15</td>
<td>78</td>
</tr>
<tr>
<td>Male Expected</td>
<td>6.0123</td>
<td>9.6196</td>
<td>82.368</td>
</tr>
</tbody>
</table>

More females than expected and fewer males than expected agreed with the statement. Fewer females than expected and more males than expected were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 8.555 with 2 degrees of freedom has probability 0.014 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A32.

*There were no significant differences in the computer-integrated and non-computer-integrated subgroups.
Warning: 50% of the cells have expected counts less than 5 in the computer-integrated group and 67% of the cells have expected counts less than 5 in the non-computer-integrated group. Chi-Square may not be a valid test.

A44: "Men make better scientists and engineers than women do."

Null Hypothesis: There are no differences between gender and responses to A44.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>0</td>
<td>3</td>
<td>62</td>
</tr>
<tr>
<td>Female Expected</td>
<td>8.773</td>
<td>10.368</td>
<td>45.859</td>
</tr>
<tr>
<td>Male Observed</td>
<td>22</td>
<td>23</td>
<td>53</td>
</tr>
<tr>
<td>Male Expected</td>
<td>13.227</td>
<td>15.632</td>
<td>69.1441</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 32.750 with 2 degrees of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A44.
Computer-Integrated

Null Hypothesis: There are no differences between gender and responses to A44 in computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>0</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td>Female Expected</td>
<td>4.3763</td>
<td>5.9677</td>
<td>26.656</td>
</tr>
<tr>
<td>Male Observed</td>
<td>11</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Male Expected</td>
<td>6.6237</td>
<td>9.0323</td>
<td>40.344</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. The Chi-Square value of 19.575 with 2 degrees of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A44 in computer-integrated classes.
Null Hypothesis: There are no differences between gender and responses to A44 in non-computer-integrated classes.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Observed</td>
<td>0</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Female Expected</td>
<td>4.4</td>
<td>4.4</td>
<td>19.2</td>
</tr>
<tr>
<td>Male Observed</td>
<td>11</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Male Expected</td>
<td>6.6</td>
<td>6.6</td>
<td>28.8</td>
</tr>
</tbody>
</table>

Fewer females than expected and more males than expected agreed with the statement or were neutral. More females than expected and fewer males than expected disagreed. * The Chi-Square value of 13.529 with 2 degrees of freedom has probability 0.001 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between gender and responses to A44 in non-computer-integrated classes.

* Warning: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.
APPENDIX E

CHI-SQUARE TABLES FOR SIGNIFICANT DIFFERENCES
IN ATTITUDE SURVEY
BY TYPE OF COURSE
Significant Differences

By Type of Course: Computer-Integrated and Non-Computer-Integrated

A21: "My calculus course covers too much material too quickly."

Females

Null Hypothesis: There are no differences between the type of course females are taking and responses to A21.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>6</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>9.6769</td>
<td>11.954</td>
<td>15.369</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>11</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>7.3231</td>
<td>9.0462</td>
<td>11.631</td>
</tr>
</tbody>
</table>

Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected agreed or disagreed with the statement. More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected were neutral.

The Chi-Square value of 6.443 with 2 degrees of freedom has probability 0.040 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course females are taking and responses to A21.
Males

Null Hypothesis: There are no differences between the type of course males are taking and responses to A21.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>16</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>19.429</td>
<td>18.857</td>
<td>17.714</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>18</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>14.571</td>
<td>14.143</td>
<td>13.286</td>
</tr>
</tbody>
</table>

The Chi-Square value of 2.198 with 2 degrees of freedom has probability 0.333 > 0.05. Therefore, we must accept the null hypothesis and conclude that there are no significant differences between the type of course males are taking and responses to A21.

All

Null Hypothesis: There are no differences between type of course and responses to A21.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>23</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>29.624</td>
<td>30.764</td>
<td>33.612</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>29</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>22.376</td>
<td>23.236</td>
<td>25.388</td>
</tr>
</tbody>
</table>

Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected agreed with the statement. More students in the computer-integrated course than
expected and fewer students in the non-computer-integrated course than expected disagreed or were neutral.

The Chi-Square value of 6.391 with 2 degrees of freedom has probability $0.041 < 0.05$. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to A21.

A50: "My family always encouraged me to take math courses."

Females

Null Hypothesis: There are no differences between the type of course females are taking and responses to A50.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>24</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>22.769</td>
<td>11.385</td>
<td>2.8462</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>16</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>17.231</td>
<td>8.6154</td>
<td>2.1538</td>
</tr>
</tbody>
</table>

More females in the computer-integrated course than expected and fewer females in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer females in the computer-integrated course than expected and more females in the non-computer-integrated course than expected disagreed.

*The Chi-Square value of 7.924 with 2 degrees of freedom has probability $0.026 < 0.05$. Therefore, we must reject the null hypothesis and conclude that
there are significant differences between type of course females are taking and responses to A50.

*Warning: 33% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

**Males**

Null Hypothesis: There are no differences between the type of course males are taking and responses to A50.

<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>32</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>29.143</td>
<td>20</td>
<td>6.8571</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>19</td>
<td>15</td>
<td>8</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>21.857</td>
<td>15</td>
<td>5.1429</td>
</tr>
</tbody>
</table>

More males in the computer-integrated course than expected and fewer males in the non-computer-integrated course than expected agreed with the statement. Fewer males in the computer-integrated course than expected and more males in the non-computer-integrated course than expected disagreed. The Chi-Square value of 3.431 with 2 degrees of freedom has probability 0.180 > 0.05. Therefore, we must accept the null hypothesis and conclude that there are no significant differences between the type of course males are taking and responses to A50.

**All**

Null Hypothesis: There are no differences between type of course and responses to A50.
<table>
<thead>
<tr>
<th></th>
<th>Agree (1 or 2)</th>
<th>Neutral (3)</th>
<th>Disagree (4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>57</td>
<td>33</td>
<td>4</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>52.412</td>
<td>31.903</td>
<td>9.6848</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>35</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>39.588</td>
<td>24.097</td>
<td>7.3152</td>
</tr>
</tbody>
</table>

More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected agreed with the statement or were neutral. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected disagreed.

The Chi-Square value of 8.776 with 2 degrees of freedom has probability .012 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to A50.

Instructions for Part C were as follows:

C. How often do you do the following things in this course? Circle the number of the answer that best describes what you do.

Circle 1 if you do it all or almost all the time.

Circle 2 if you do it more than half the time.

Circle 3 if you do it about half the time.

Circle 4 if you do it less than half the time.

Circle 5 if you do it rarely or never.
C3: Use a computer at school for numerical computation.

Females

Null Hypothesis: There are no differences between the type of course females are taking and responses to C3.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>15.938</td>
<td>21.062</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>12.062</td>
<td>15.938</td>
</tr>
</tbody>
</table>

More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 25.903 with 1 degrees of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C3.
Males

Null Hypothesis: There are no differences between the type of course males are taking and responses to C3.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>39</td>
<td>17</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>25.714</td>
<td>30.286</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>19.286</td>
<td>22.714</td>
</tr>
</tbody>
</table>

More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time. The Chi-Square value of 29.616 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C3.
Null Hypothesis: There are no differences between the type of course and responses to C3.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>66</td>
<td>28</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>42.727</td>
<td>51.273</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>9</td>
<td>62</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>32.273</td>
<td>38.727</td>
</tr>
</tbody>
</table>

More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 54.008 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C3.
C7: Use a calculator to graph a function or equation.

**Females**

Null Hypothesis: There are no differences between the type of course females are taking and responses to C7.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>11.954</td>
<td>25.046</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>9.0462</td>
<td>18.954</td>
</tr>
</tbody>
</table>

The Chi-Square value of 1.201 with 1 degrees of freedom has probability 0.273 > 0.05. Therefore, we must accept the null hypothesis and conclude that there are no significant differences between the type of course females are taking and responses to C7.

**Males**

Null Hypothesis: There are no differences between the type of course males are taking and responses to C7.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>20.571</td>
<td>35.429</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>15.429</td>
<td>26.571</td>
</tr>
</tbody>
</table>

More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected.
used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 7.409 with 1 degree of freedom has probability 0.006 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between the type of course males are taking and responses to C7.

All

Null Hypothesis: There are no differences between the type of course and responses to C7.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>42</td>
<td>52</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>33.042</td>
<td>60.958</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>16</td>
<td>55</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>24.958</td>
<td>46.042</td>
</tr>
</tbody>
</table>

More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 8.702 with 1 degree of freedom has probability 0.003 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C7.
C8: Use a computer to graph a function or equation.

**Females**

Null Hypothesis: There are no differences between the type of course females are taking and responses to C8.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>18.785</td>
<td>18.215</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>14.215</td>
<td>13.785</td>
</tr>
</tbody>
</table>

More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 31.575 with 1 degrees of freedom has probability $0.000 < 0.05$. Therefore, we must reject the null hypothesis and conclude that there are significant differences between the type of course females are taking and responses to C8.
Males

Null Hypothesis: There are no differences between the type of course males are taking and responses to C8.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>40</td>
<td>16</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>27.429</td>
<td>28.571</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>8</td>
<td>34</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>20.571</td>
<td>21.429</td>
</tr>
</tbody>
</table>

More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time. The Chi-Square value of 26.351 with 1 degrees of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between the type of course males are taking and responses to C8.
Null Hypothesis: There are no differences between the type of course and responses to C8.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>71</td>
<td>23</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>47.285</td>
<td>46.715</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>12</td>
<td>59</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>35.715</td>
<td>35.285</td>
</tr>
</tbody>
</table>

More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 55.619 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C8.
C9: Use a computer to do symbolic manipulation.

Females

Null Hypothesis: There are no differences between the type of course females are taking and responses to C9.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>12.523</td>
<td>24.477</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>9.4769</td>
<td>18.523</td>
</tr>
</tbody>
</table>

More female students in the computer-integrated course than expected and fewer female students in the non-computer-integrated course than expected used it half of the time or more. Fewer female students in the computer-integrated course than expected and more female students in the non-computer-integrated course than expected used it less than half the time. The Chi-Square value of 15.665 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between the type of course females are taking and responses to C9.
Males

Null Hypothesis: There are no differences between the type of course males are taking and responses to C9.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>32</td>
<td>24</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>22.286</td>
<td>33.714</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>16.714</td>
<td>25.286</td>
</tr>
</tbody>
</table>

More male students in the computer-integrated course than expected and fewer male students in the non-computer-integrated course than expected used it half of the time or more. Fewer male students in the computer-integrated course than expected and more male students in the non-computer-integrated course than expected used it less than half the time. The Chi-Square value of 16.411 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between the type of course males are taking and responses to C9.
Null Hypothesis: There are no differences between the type of course and responses to C9.

<table>
<thead>
<tr>
<th></th>
<th>(1, 2 or 3)</th>
<th>(4 or 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-I Observed</td>
<td>58</td>
<td>41</td>
</tr>
<tr>
<td>C-I Expected</td>
<td>55.261</td>
<td>58.679</td>
</tr>
<tr>
<td>Non-C-I Observed</td>
<td>38</td>
<td>62</td>
</tr>
<tr>
<td>Non-C-I Expected</td>
<td>41.739</td>
<td>44.321</td>
</tr>
</tbody>
</table>

More students in the computer-integrated course than expected and fewer students in the non-computer-integrated course than expected used it half of the time or more. Fewer students in the computer-integrated course than expected and more students in the non-computer-integrated course than expected used it less than half the time.

The Chi-Square value of 32.941 with 1 degree of freedom has probability 0.000 < 0.05. Therefore, we must reject the null hypothesis and conclude that there are significant differences between type of course and responses to C9.
APPENDIX F

LETTERS
November 2, 1993

Attorney Paul M. Shapiro  
Assistant Attorney General  
Attorney General's Office  
U-177  
University of Connecticut

Dear Attorney Shapiro:

Thank you very much for the time you spent with me on the telephone last week. I understand from our conversation that it is legally permissible and in conformity with University policy for me to share some data with a researcher in Mathematics Education at the University of Massachusetts, Amherst.

As we discussed, the background of this is as follows. The University's Office of Institutional Research tracked the performance of all students who took first-year calculus at any branch of the University during 1989—1990. They generated a large file that contains the name, social security number, gender, ethnicity, SAT scores, high school class ranks, course grades in calculus, membership in standard (control) or experimental calculus sections, and a list of subsequent courses and grades in these courses for which calculus is prerequisite.

To avoid violation of privacy and confidentiality of student records, Professor Uwe Koehn of Statistics has agreed to run a program on the file that will remove the name and social security number of each student, but retain the other data. This will allow the UMass researchers to attach some anonymous system of identification in place of the social security number and carry out data analysis similar to that performed here by Professor Koehn for our project.
For your information, the analysis of such data is part of the required assessment activity for two National Science Foundation funded grants the Department has received since 1991 to support improvements of the effectiveness of calculus instruction. (An enclosure describes this activity in more detail.) We anticipate that the analysis of our data by an external researcher can have a favorable impact on the project and contribute positively to its standing within the broader mathematical community in general, and the National Science Foundation’s Directorate for Education and Human Resources in particular.

Thank you for your attention to and advice about the foregoing.

Sincerely,

James F. Hurley
Professor

JFH:nh

Enclosure

cc: M. Connors, U. Koehn, F. Winschel, C. Vinsonhaler, W. Wickless, R. Hansell, A. Stein, S. Kim
I am responding to your memorandum of November 2.

I do not have a problem with the sharing of data with UMass researchers in the manner outlined in your memorandum. The Family Educational Rights and Privacy Act (FERPA) is not violated if personally identifying information is not provided to UMass. The elimination of name and social security number from the run that UMass will receive will accomplish this.
November 9, 1993

Mrs. Mary Ann Connors
19 Sterling Drive
Easthampton MA 01027

Dear Mrs. Connors:

This letter provides written confirmation of our telephone and electronic-mail discussions about your desire to analyze data collected here as part of the assessment activity associated with the National Science Foundation Grant Number USE-9153270, titled "Integration of Computing into Main-Track Calculus."

I have conferred with the State of Connecticut Assistant Attorney General and University Attorney, Paul Shapiro, who advises me that it is permissible to supply you with raw data that contains no means of identifying any individual student. My statistical consultant, Professor Uwe Koehn, has agreed to run a program on our current data set to remove the name of each student, and generate a new student number that will be different from the student's social security number and will replace the social security number in the data set. (It will not be possible to reconstruct the student’s actual social security number from the new number.) All other information about the students, such as gender, ethnicity, course grades, subsequent courses taken, SAT scores, majors, etc., will be retained in the new data set.

That should permit you to carry out analysis of the data to investigate by gender and ethnicity the student performance in our computer-integrated sections and in traditional calculus sections during 1989-90 and thereafter in follow-up courses for which calculus is prerequisite.

As soon as I have received written authorization from the Assistant Attorney General to release the data to you, I will send you an IBM-PC compatible 3.5-inch diskette containing the reworked data. My colleagues in our calculus project join me in extending every good wish to you in studying our data, and look forward to learning of the results you obtain from your analysis.

Sincerely,

[Signature]

James F. Hurley
Professor

cc: R. Hansell, S. Kim, U. Koehn, P. Shapiro, A. Stein, C. Vinsonhaler, W. Wickless
Dear Professor Hurley:

Enclosed please find a copy of my dissertation proposal and interview consent form. My Dissertation Committee has approved my proposal and the Human Subjects Review Committee has approved my interview plans and interview consent form.

Thank you for your assistance in my study of your calculus project. Please let me know if there are any other requirements to proceed with this study at the University of Connecticut.

I am looking forward to visiting your department Friday February 18, 1994 to begin observations and interviews on the computer-integrated and non-computer integrated first year calculus courses.

Sincerely yours,

Mary Ann Connors
19 Sterling Drive
Easthampton, MA
(413) 527 - 7072
e-mail: mconnors@math.umass.edu
February 18, 1994

Dear Calculus Student:

Calculus courses are a filter for many Americans who wish to pursue majors in computer science, engineering, mathematics, science, or statistics - disciplines for which calculus is a direct prerequisite. This critical situation threatens the nation's supply of scientists and engineers and its capacity to compete in international economic enterprises. In order to make calculus a pump rather than a filter in the scientific pipeline, the University of Connecticut at Storrs is one of the nation's leaders in reforming the teaching and learning of calculus. To better understand how college students learn calculus, you are being asked to participate in a confidential interview examining attitudes and opinions of calculus students in computer-integrated and non computer-integrated first year main-track calculus courses at the University of Connecticut at Storrs during Spring semester 1994. At the end of fall semester 1993 you were asked to complete a confidential questionnaire developed by the University of Connecticut Institute for Social Inquiry and slightly modified to include gender and ethnicity. The purpose of this interview is to gain deeper insight on some items in the questionnaire. If you choose to participate in the confidential interview in person, via telephone and/or e-mail, please read and complete the attached written consent form.

You may request a copy of the results from the interviewer upon completion of the study. The results of the study will be used as part of my doctoral dissertation, publications in scholarly journals and/or presentations at professional meetings; however, the data will be presented by pseudonym, gender and/or in the aggregate form. In no way will this information affect your affiliation with the University of Connecticut.

This project has been reviewed by the University of Massachusetts Human Subjects Review Committee. If you have questions regarding participation in this study, please contact me. I am a doctoral student in the Mathematics, Science and Instructional Technology Program at the University of Massachusetts School of Education.

Thank you for your consideration of participating in this project.

Sincerely yours,

Mary Ann Connors

(413) 545-0907
E-mail: mconnors@math.umass.edu
WRITTEN CONSENT FORM

An Analysis of Student Achievement and Attitudes by Gender in Computer-integrated vs. Non-computer-integrated First Year College Mainstream Calculus Courses

I, Mary Ann Connors, am a doctoral student at the University of Massachusetts Amherst. The subject of my doctoral research is an analysis of achievement and attitudes by gender in computer-integrated vs. non computer-integrated mainstream calculus courses.

I am interested in learning about and comparing the attitudes and opinions of calculus students in computer-integrated and non computer-integrated courses at the University of Connecticut at Storrs during Spring semester 1994. I will conduct thirty minute interviews with each student in person, by telephone and/or e-mail to gain insight on attitudes with regard to calculus, mathematics and using the computer as a learning tool.

Each in person and/or telephone interview will be audiotaped and later transcribed. For your protection, your name will not be used. Transcripts will be typed with initials for names and (in final form) material from the interviews will be reported by pseudonym, gender and/or in the aggregate and not by the individual's name.

The results of this research project will be used as part of my doctoral dissertation, presentations at conferences, and/or publications.

As a participant you have the following rights:
1. to participate or not participate without any prejudice to you;
2. to review the materials of the study;
3. to withdraw from the process at any time.

In signing this form, you are also assuring me that you will make no financial claims for the use of the material in your interview. You are also stating that no medical treatment or any liability will be required by you from the University of Massachusetts or from me should any physical injury result from participating in this interview.

I, ____________________, have read this consent form and agree to be an interview participant in the research project proposed above.

________________________________________  _____________  ___________  ___________
Signature of Participant                  Date                  Phone                   E-mail

________________________________________  ___________
Signature of Interviewer                 Date
Dear Mrs. Connors:

This letter provides written confirmation of our telephone and electronic-mail discussions about your desire to analyze data collected here as part of the assessment activity associated with the National Science Foundation Grant Number DUE-9252463. Connecticut State Assistant Attorney General and University Attorney, Paul Shapiro, has advised me that it is permissible to supply you with raw data that contains no means of identifying any individual student. My statistical consultant, Professor Uwe Koehn, has run a program on our current data set to remove the name of each student, and generate a new student number, different from the student's social security number, to replace the social security number in the data set. (It will not be possible to reconstruct the student's actual social security number from the new number.) All other information about the students, such as common final exam scores from Fall, 1993 and Spring, 1994, gender, ethnicity, course grades, subsequent courses taken, SAT scores, majors, etc., will be retained in the new data set. We are also happy to share with you the data on confidential student attitude survey given at the end of Fall, 1993.

That should permit you to carry out analysis of the data to investigate by gender and ethnicity the student performance in our computer-integrated sections and in traditional calculus sections during 1993–1994.

My colleagues in our calculus project join me in extending every good wish to you in studying our data, and look forward to learning of the results you obtain from your analysis. As previously discussed, we welcome the interviews you are conducting this Spring with current and former students to gain insight on attitudes with regard to calculus, mathematics, and using the computer as a learning tool.

Sincerely,

James F. Hurley
Professor

cc: S. Kim, U. Koehn, J. Tollefson


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