Laboratory Approaches in Undergraduate Mathematics

January 14, 1993

All of the projects represented in this poster session have received funding from the National Science Foundation through its Division of Undergraduate Education's Instrumentation and Laboratory Improvement (ILI) or Leadership in Laboratory Development (LLD) programs. This booklet contains brief project descriptions submitted by poster session participants as well as a listing of recent ILI and LLD grants in Mathematics.

—Arnie Ostebee

Sample Lessons for a Mathematics Computer Lab

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During the 1989–90 academic year, Livingston University was awarded a National Science Foundation grant to furnish a mathematics laboratory for undergraduate mathematics. The lab consists of fifteen IBM PS-2 Model 55s, one Model 70, and five printers, including one laser printer.

Livingston University, the smallest of the state-supported institutions in Alabama, was chartered in 1835. It is located in rural west Alabama, approximately 120 miles southwest of Birmingham, Alabama.

The University endeavors to provide an environment for educational excellence. With the addition of the Mathematics Lab, LU students are exposed to the latest in technology. Students are able to visualize some of the more complicated mathematical problems through the use of *Derive*, *Gyro Graphics*, and some of the programs from the NSF grant at the University of Arizona. By using these programs, the students' capabilities in mathematics have been enhanced. The new graphing utilities allow students to explore functions that are extremely difficult to graph by hand.

The lab was first used for the teaching of calculus. It is now being used by professors to assist in the teaching of college algebra, pre-calculus mathematics and finite mathematics. Use of the lab is scheduled, in advance, by each professor. The lab is available for student use on week days, a couple of nights during the week, and limited hours on the weekend.

During the poster session, we would like to share this material with other interested teachers. We shall have pictures showing the set-up of the lab, responses from students about the lab, and some of the lab worksheets we have used. The worksheets will cover topics taught in college algebra, pre-calculus, calculus I, II, III, and college geometry.

Capstone Experiences for Mathematics Majors

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Mathematics majors at Northern Arizona undertake a substantial modeling project that brings the power of modern computers and software to bear on realistic problems. Descriptions of the specific approaches used in three tracks—actuarial science, applied mathematics, and statistics—along with the overall course and computer laboratory structure will be presented.

Mac Lab and Demo Classroom for Calculus, Ordinary Differential Equations, Linear Algebra

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A computer component is being introduced into the multivariable calculus and differential equations courses. Students are gaining insights afforded by newly developed graphics software, are empowered with the ability to use computer algebra systems for numeric and symbolic computation, are experimenting with vector fields and their associated flows, and are visually investigating examples that illustrate the theory of vector analysis and Fourier approximations.

We have inaugurated a 17-station Mac lab and a classroom with a Quadra and an overhead projector. Software includes *Mathematica*, *Theorist*, and *True Basic*. A sample of student projects will be on display.

Laboratory Enhancement for Applied Mathematics

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The applied mathematics degree program at San Francisco State University requires students to complete a one-year project course during their senior year. Teams of students work on a variety of problems developed by faculty members in co-operation with government and industry. Projects have come from such areas as pension funding analysis, statistical analysis of cancer drug manufacturing, truck routing and scheduling, and soil analysis. The intent of this activity is to make students aware of the "real world" and its mathematical problems and prepare them for careers in applied mathematics.

Through a successful ILI Grant, we have been able to secure laboratory space from the university and outfit this space with four 486SX machines and two SUN workstations and the necessary auxiliary support to support applied mathematics projects in a manner similar to an industrial setting. At this writing we have obtained delivery of equipment and have just set the workstations in place so that the laboratory for the student projects will be running at full steam for the coming spring semester.

For further information please contact Professor David Ellis, Principal Investigator (415-338-1026) or at e-mail.

Toward Making Mathematics a Laboratory Science

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In summer '91 the Colorado School of Mines (CSM) was awarded an NSF-ILI grant to establish a classroom/lab for doing mathematics. The new lab accommodates 48 students and has 24 student NeXT-stations together with a NeXT server. The school has added a high-quality color projection system, helping make a first rate facility for classroom teaching and mathematics laboratory.

The lab has provided the impetus for our faculty to modernize the calculus sequence—making it less tedious, better focused and, we believe, more memorable. We have made some, although not dramatic, progress toward making calculus more of a "laboratory science".

Since Fall '91 all freshmen at CSM have been exposed to the revised curriculum and all learn the elements of *Mathematica.* They all meet in the lab at least hour per week as a classroom, and average about this amount during evenings or weekends, in pairs, working on *Mathematica* assignments. These assignments are designed to reenforce a central mathematical concept and/or explore a scientific application.

Introducing Computer Technology in Mathematics Teacher Training Programs

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With the increased use of the computer in the classroom it is becoming imperative that prospective mathematics teachers know how to use computers and appropriate software in ways that augment the learning process as opposed to just adding "glitz" to the classroom.

Thus, the purpose of this proposal is to acquire the mathematical software and hardware to augment our already existing courses to provide our teacher graduates with the best background possible to help them effectively use computer software that is now, and will be, available in a way that is truly beneficial to their students.

The grant was used to purchase discovery type software that is currently available at the secondary and middle school level. The curriculum in each of our mathematics teacher training classes was modified to include training in the use of the various software packages. Students were then required to create computer projects which incorporated the software into lesson plans for their appropriate level, secondary or middle school. Several of the students' projects will be available at the poster session.

Integrating Mathematica *into a Reformed Calculus Curriculum*

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Metropolitan State College of Denver received an NSF–ILI grant of slightly over $50,000 to fund a project integrating technology into a reformed curriculum for the three-semester sequence Calculus I, II, and III. This grant enabled MSCD to establish a computing laboratory containing 22 NeXT workstations, each running *Mathematica* with 16 mega-bytes of RAM. We are currently integrating this lab into our curriculum by writing modules (in the form of Mathematica notebooks) to replace the traditional treatment of certain topics in our standard textbook (*Calculus, Second Edition*, James Stewart). We spend about one class period per week (out of four) in the laboratory.

At this session we will describe our laboratory and our project in further detail; we will exhibit hard copies of some of our modules in their current (far from final) form.

A Mathematics Resource Center for Senior Research Projects

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The aim of this project is to improve the existing undergraduate study room/library by installing computer resources appropriate for undergraduate research in mathematics. The resulting Mathematics Resource Center will play a significant role in the development of the mathematics major at USC, increase the visibility of mathematics on campus, and serve as a meeting place for individual and group study by math majors.

Undergraduate research and capstone experiences have been identified by the mathematics, education, and industrial communities as a valuable component in undergraduate math education. Accordingly, the University of Southern Colorado will be requiring a Senior Research Project of all majors beginning in the Fall of 1992.

The Mathematics Resource Center will assist mathematics majors in the completion of their Senior Research Projects. We have chosen 3 Macintosh IIci's as most appropriate for this purpose. Applicable software includes *Mathematica*, a variety of statistical packages, and MATLAB. These resources will enable our students to pursue a wide variety of research projects. The Center will promote the study of real world problems, and expose students to state-of-the-art technology.

Undergraduate Mathematics: Technology to Improve Student Capabilities

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The Department of Mathematical Sciences at the University of Delaware is continuing a long-term program to enhance the mathematical capabilities of undergraduate students by integrating graphical, numerical and symbolic mathematical software across a broad spectrum of the curriculum. Such software has already been integrated into the last two semesters of the three-semester calculus sequence for engineers, mathematicians, and scientists (mostly physical sciences).

The current phase consists in adapting, refining, and scaling-up pilot programs in the first courses in differential equations and linear algebra. Each session of these courses will be conducted by a professor in a computer classroom with 25 students and 25 Sun workstations. Students have already had experience using *Derive* and *Maple* in this classroom on individual Sun workstations in each meeting of third-semester calculus. In the differential equations and linear algebra courses, MATLAB (and other local packages) will constitute the principal software used.

Interactive Mathematics Text Project

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The MAA's Interactive Mathematics Text Project (IMTP) has as its goal the improvement of student learning of mathematics through the use of interactive texts. An interactive mathematics text is a computer-based document from which numeric, symbolic, and graphical commands can be executed with the result appearing in the document. The IMTP will run 12 week-long workshops during the summer of 1993. At these workshops participants will be given an overview of interactive texts and their use in instruction, will spend time using a text, receive instructions on how to author a text, and will work closely with the workshop staff and each other on the creation of a short text on a topic of their choice.

Materials describing the project and the summer workshops will be available at the poster session.

IMTP Workshops Using MathWindows: A new tool for writing and exploring math interactively

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The MAA's Interactive Mathematics Text Project (IMTP) is aimed at encouraging both the writing of interactive math books and their use by students to explore—to read, play, compute, visualize, and learn mathematics. Currently most electronic math notebooks are written using *Maple*, *Mathcad*, or *Mathematica*, and in form they are long scrollable documents. A new authoring platform designed specifically for interactive math books is now being completed and will be commercially available in mid-93. It consists of a toolkit (MathWindows) and a frontend (TIM) both running under Microsoft Windows. Authors may also use ToolBook or Visual Basic as the frontend to MathWindows if they prefer.

MathWindows will be used in 3 of the summer '93 IMTP workshops (2 with TIM as frontend, 1 ToolBook). Books using MathWindows are paginated, and authors can arrange on each page the built-in display windows (text, math edit, graph2d, graph3d, animation, data, programming) and user gadgets (sliders, buttons, check boxes). The author writes short scripts to activate the display objects and gadgets and so constructs a math microworld, a learning environment initially as narrowly focused or as free for exploration as the teacher deems appropriate for the topic. But even an apparently restricted setting needn't hinder an inquisitive student, exploratory tools are but a menu away!

Using a Computer Algebra System to Convert Calculus (and related courses) Into Formal Laboratory Courses

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The Department of Mathematics and Computer Science at Georgia Southern University has established a sophisticated microcomputer teaching laboratory which houses twenty-nine Macintosh computers (SE/30, IIsi, IIci) equipped with *Mathematica*. The Department has used the powerful and sophisticated capabilities of this technology in numerical computation, symbolic computation, and graphics to enhance and improve the instruction of the calculus sequence, differential equations, and applied mathematics. These courses have been converted into laboratory courses which consist of four lectures and one two-hour laboratory per week.

The Department has also used powerful instructor workstations and an overhead projection system for the development of materials for the courses, training of faculty and student assistants, and classroom demonstrations. The materials developed have been used for classroom presentations, assignments for laboratory sessions, and assignments to be completed outside of class. A laboratory manual and several other reference manuals have been published as a result of the project.

Current technology has been brought into the classroom and made an integral part of these courses. The students have gained experience with this technology which will benefit them in the job situations that they will encounter. The technology has been used to handle tedious and complex manipulations so that more emphasis can be placed on understanding the material presented in these courses.

This project has also been supported by an Equipment Grant from Apple Computer, Inc., and by the Educational Grant Program of Wolfram Research, Inc.

A Networked Computer Environment for Laboratory-Based Calculus

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Lake Forest is in the second year of an ILI grant that enabled us to purchase and network 22 486's PC's in a computer lab, 2 classrooms, and 4 faculty offices. The grant also enabled us to purchase copies of *Derive* to be used in a local area network with these machines. With this hardware and software, we have implemented a weekly lab in all sections of first-year calculus.

The labs use the ACM/GLCA "Learning by Discovery" laboratories that were developed through a large NSF grant (directed by Wayne Roberts of Macalester College) for preparation of calculus materials. The labs were written to be software independent and we have used them with the computer algebra system *Derive*. Roughly 8–10 of these labs are used in each semester of first-year calculus in the format described below. The project has so far involved six different faculty members. Planning and training was done in August of 1991 during a one-week workshop supported by Lake Forest College. This consisted of working with the hardware, getting comfortable with *Derive*, testing and adapting the ACM/GLCA materials, and discussing strategic and philosophical issues related to implementing a weekly lab.

Several different formats for weekly labs have been tried, based upon scheduling constraints and individual preferences. All involve setting aside an approximately weekly meeting in the laboratory, having students work cooperatively in groups of two or three, giving students hard copies of the labs in advance, and requiring a lab write-up based upon the lab experiences. Some differences in approach related to the length of the lab (varying from one to two hours), how soon write-ups were due (varying from the next class meeting to a week later), and whether write-ups were to be done individually or jointly.

A spinoff of this lab experience has resulted in a second calculus project using the same hardware the *Mathematica*, rather than *Derive*. Since this effort is in its first semester and involves my individual efforts in Honors Calculus, I will just note that it involves use of *Mathematica for Windows* on a collection to 20 notebooks that have been written by Stan Wagon and me. These notebooks will be published in book and electronic form by W.H. Freeman later this year under the title *Animating Calculus: Mathematica Notebooks for the Laboratory*.

At this point only informal evaluations of the laboratory approach have been made. Students are enthusiastic about the actual time spent in the laboratory and the use of technology in exploring ideas and doing more realistic kinds of calculations. They report that the "discovery" approach is both frustrating (in contrast to the "template" approach they got comfortable with in high school) and

rewarding (when they succeed in figuring things out on their own). The cooperative approach is generally appreciated and succeeds in stimulating involvement and excitement. There is a reasonably widespread (and no doubt correct) view that the laboratory component adds to the weekly work load provides additional challenge. This, together with the fact that student assistants and previous calculus students have not had to do this, has resulted in negative comments bout the labs from more than an occasional student.

Learning Mathematics with Computers

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Franklin College is a liberal arts college with 900 students located twenty miles south of Indianapolis. Approximately 80% of the students live on campus.

Franklin includes in its graduation requirements a mathematics course designed to acquaint students with the breadth of mathematics. This course (Mathematical Models—GE 103) does not rely heavily on a school mathematics background, but does expect minimal algebraic and arithmetic skills. Students who take a calculus course may substitute that course for GE 103 in meeting graduation requirements.

As a result of the NSF grant received by Franklin College in the ILI program, all Franklin College students will utilize the computer in mathematical applications. About one-half of the students will satisfy graduation requirements with GE 103, with the remainder taking a calculus course (either MAT 130 or MAT 141). The schedule of the undergraduate computer laboratory includes weekly sessions for each of these courses in addition to the Basic Statistics course, the computer literacy courses, and the courses in mathematics for elementary teachers. Thus, most students will take more than one course which will be scheduled weekly in the computing laboratory.

The lab is to be outfitted with 14 Zenith 486's set up in two-person workstations, anticipating that students will work in pairs. It is our expectation that we will acquire sufficient machines in the near future to allow them to work individually. The software utilized in this laboratory includes *Derive*, *Quik-Calc*, *Minitab*, *Quattro Pro*, and *LOGO*. A two-year Curriculum Development grant from Lilly Endowment, Inc., has provided faculty released time and summer stipends to produce the needed curriculum materials.

Computerization Across the Upper Level Mathematics Curriculum

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At Franklin College we have used an ILI grant from NSF to establish a computerized classroom/laboratory which provides daily access to all upper-level mathematics classes. The classroom is designed so that each student is provided with a computer and adequate desk space so that the use of technology can be incorporated into class sessions to whatever degree is necessary. The lab currently consists of twelve Zenith 486's networked with a MicroVAX file server and running *Mathematica*, *Derive*, *Quik-Calc*, and other specialized course software. A two-year Curriculum Development grant from Lilly Endowment, Inc., has provided faculty released time and summer stipends to produce the needed curriculum materials.

Instruction in Mathematica syntax is interwoven with a week of review at the beginning of Calculus III, which is the students' first exposure to the new lab. *Mathematica* serves as a common thread throughout the remainder of the students' mathematics program. Discovery learning and cooperative learning are emphasized in the classroom, with students are encouraged to view mathematics as an exploratory science and technology as a tool to aid in their investigations.

An Upper-Division Mathematics Computer Classroom/Laboratory

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This poster discusses Rose-Hulman's Theorodrome—an upper-division mathematics classroom/laboratory that was put together in the Spring of 1992 with the support of NSF–ILI grants (Equipment and Leadership). Topics include the motivation for, and the philosophy of, the Theorodrome; the Theorodrome's design; the hardware and software used in the Theorodrome; an outline of a discrete mathematics project.

Chaotic Dynamical Systems Laboratory

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The Bates Mathematics Department received NSF support for the purchase of three Silicon Graphics Personal Iris workstations, for use as laboratory tools

in the study of chaotic dynamical systems (CDSs). Three courses will eventually make use of them; one has been offered once already. The great speed of the machine makes it possible for students to quickly produce images of CDSs in order to answer "what if" types of questions. So far, students have looked at traditional topics such as the Mandelbrot set, Julia sets, and bifurcation diagrams; there are plans to consider other topics. The advanced sound generating capability of the workstations is used to study orbits of points in novel ways. We have also found interesting ways to use the advanced three-dimensional drawing and animation capabilities of the machines in studying CDS.

The poster session will describe some of the programs we have written and others we plan to write for the machines, lab exercises, successes and difficulties in implementing the project, and other ways the workstations have been used.

Project CALC and Mathematica

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Project CALC ("Calculus As a Laboratory Course"), developed at Duke University with support from the National Science Foundation, is part of a nationwide effort to revitalize the teaching of calculus. The project represents a major revision of the calculus curriculum, built around 1) selected problem areas in the natural and social sciences that motivate the introduction of calculus techniques; 2) a discovery-based computer laboratory; and 3) writing assignments which place the emphasis of the course on conceptual understanding, not solely on computational skills.

At Bowdoin the Project CALC materials have been reformulated around *Mathematica*, a sophisticated integration of text-processing, numeric and symbolic computation, graphics, and programming. Grants from both the National Science Foundation and the Alden Trust have supported this conversion, which began in the fall of 1990. *Mathematica* notebooks for over forty laboratories currently exist, covering all three semesters of calculus. These notebooks have been designed for use with Macintosh computers equipped with 13-inch color monitors. Versions of the notebooks have also been produced for NeXT computers.

This semester there are two sections of Project CALC at the college—one each of Calculus I and Calculus II—with a total enrollment of forth-five students. Next semester one section each of Calculus II and Calculus III will be offered. Each course has a weekly two-hour computer laboratory session. Current plans call for the use of the laboratories in all sections of calculus starting in the fall of 1993.

Printed versions of the laboratory notebooks are published by D.C. Heath. Electronic versions of all the materials are currently distributed for free via FTP transfer. Dissemination via disks is also done, although a small fee is charged to cover costs.

Computer Laboratories for a Restructured Calculus Curriculum

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Our ILI grant helped us purchase computer laboratory equipment to support implementation of our test site for Duke University's Project CALC. With the grant and matching funds we were able to purchase two laboratories of IBM 386SX-based machines, one of which is under direct control of our Department, and the other located within the University's Academic Computing Center. Prior to receiving the grant we were operating with a conglomeration of IBM and IBM clone machines (8086 or 8087) located in our Center and, hence, shared with all other departments.

With this new equipment we run a totally laboratory-based calculus program. The decision to use this format was initially forced on us by the inadequacy of our computing equipment. The first Project CALC test site was begun 2 1/2 years ago on the old equipment. It was in its last semester when the new equipment was received; since the project had been moving along successfully (77% retention rate), the format was continued. A new test site class was begun this year with a slightly modified format.

The Project CALC model we use has students working in groups of two or three (preferably two) at the computer on specially-designed laboratory exercises ad projects. The text is *The Calculus Reader* by David A. Smith and Lawrence C. Moore. Students have reading assignments to do in the text before starting a laboratory exercise. Lecture time is kept to a minimum, generally on an introductory or as needed basis. In addition to the lab work, students have regularly-scheduled homework assignments that are graded.

Our laboratory is open 30 hours per week, including Saturday hours, for "walk-in" student use under supervision of a work-study student. In addition, the Center laboratory is open 100 hours, including weekend hours, per week. Students use this time as needed to complete assignments.

The poster session will illustrate the philosophy behind our program and provide some samples of our materials.

Laboratory for Mathematical Experimentation

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The prerequisite for the Laboratory is one semester of calculus. Students are encouraged to take the Lab before deciding on a major; all mathematics majors must take the Lab. Students explore a wide range of topics in the Lab's six required modules. They carry out their experimentation in groups, but each student writes her own report. In it the student describes the design of her experiments, states her conjectures, gives the evidence supporting them, and—where possible—proves her conjectures. The emphasis is on asking good questions, reasoning carefully, and writing clear, precise prose. Reports are often returned to the student for rewriting. For extra credit, a student may design a project herself, carry it out, and write a report. Most students do at least one independent project.

Every offering of the course includes at least one module on iteration of functions, so that students can work on ideas related to limits and convergence. (The Lab replaces a course that used to provide preparation for junior/senior Real Analysis.) Other modules may include constructing difference sets in the integers modulo m, sieving for primes, coloring graphs, and looking at sums of random variables. With support from an NSF curriculum grant, over the next three years additional modules will be developed and all of the modules will be written up in exportable form. The goal is to permit each instructor to choose six from a library of modules, so that the content of the Lab varies from semester to semester.

The course was made possible by a successful NSF–CSIP proposal for the computers to equip the Lab in 1987. Mark Peterson taught a pilot section of the course to upperclass majors in the fall of 1988. His students debugged projects and assisted with course development. The first regular offering of the Lab was in the spring of 1989, by Harriet Pollatsek and Robert Weaver. The course has been offered every semester since, and student enthusiasm has consistently been very high. Additional modules were developed in 1990–91 by J. William Bruce, visiting Mount Holyoke from the University of Liverpool with support from IBM/Sloan and Five Colleges, Inc.

Currently, the course meets twice a week for an hour and fifty minutes in a laboratory equipped with ten IBM PC's (486 machines). Most modules involve experimentation on these machines using simple programs written in BASIC or PASCAL or using other software. Some (e.g., the simulations involving sums of random variables) require the use of the department's Suns. During the laboratory periods, students work on their experiments and discuss their results, both in their small working groups and with all of the class. The instructor does very little lecturing, much more guiding and encouraging and asking questions.

The Northeastern University Excel Mathematics Program

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At Northeastern we are trying to combine the innovative ideas of Uri Treisman with elements of calculus reform and the use of computer labs. Professor Treisman (University of Texas at Austin) discovered that students who worked together in small groups under the supervision of more advanced students ("mentors") could, in a carefully designed program, dramatically increase their ability in mathematics. These "Treisman" programs, designed to improve the mathematics education of African-American and Hispanic students at Berkeley, have proved to be spectacularly successful—there and at several other institutions where they have been tried.

Northeastern's EXCEL program is more than just a copy of Treisman's original ideas. While most Treisman programs have been implemented within a very traditional mathematics curriculum, we decided that we would use his methods in the context of modern calculus "reform." For a number of years we have been shaping our calculus curriculum around the central ideas of differential equations and mathematical modeling. We introduce logarithmic and exponential functions very early in our freshman sequence, and use flow or direction fields soon after to describe differential equations. We accentuate numerical methods throughout our calculus sequence, and all science and engineering students are required to do a project which involves using differential equations to model a physical situation of their choosing; the students have come up with topics such as wind surfing, alcohol fermentation, and aspects of ecology.

Students are expected to use computers as tools in their calculus courses. At present, each of the three quarters of freshman engineering/science calculus requires 5 computer lab problem sets. Some of these use inexpensive plotting software to study, for example, curves, flow-fields, and Newton's method. More recently, we have been using spreadsheets because of their visual impact, their obvious numerical orientation (with graphs coming from numbers, not from magic), and their flexibility. One of our goals is to have first-year students working in the computer lab once a week on projects of varying length.

Recently we were fortunate enough to obtain funds from NSF, the Northrup Corporation, and the University to build our own computer lab. The EXCEL lab is designed in a way which maximizes student interaction. The computer tables are hexagonal and the chairs are swivel base, with casters, to encourage group and intergroup activity. As with other aspects of Treisman programs, the EXCEL lab is staffed by student mentors. These mentors are specially trained in the use of the software, and they are themselves "graduates" of our calculus sequence and computer labs. They understand the educational content of the exercises, and

know how to ask leading questions and suggest lines of attack without giving away answers. Choosing and training our student mentors is one of the most important parts of our program.

Currently, all of our first-year science and engineering students (nearly 500) are involved in the reformed curriculum and computer lab. We also have one (voluntary) section of freshman calculus taught in the Treisman style; in subsequent years, as more student mentors can be recruited from the program, we hope to teach all sections this way, and expand the entire program beyond the freshman year.

Maple *Calculus Labs in a Unix Workstation Environment*

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In the Spring of 1991, we received a grant from the NSF–ILI program that enabled us to set up a computer laboratory consisting of 17 networked DECstation 3100 workstations. This lab was used in a pilot calculus course in the 1991–92 academic year. This year, we expanded the lab to 23 machines and are running two sections of the course.

The course includes weekly 1–2 hour sessions in the lab. Students work in teams of two on exploratory exercises, utilizing the CAS *Maple*. Functions of more than one variable and parametric curves are introduced early in the course, using *Maple* for visualization. The emphasis in the course is on applications of calculus. For example, as part of a lab dealing with solids of revolution, the students are asked to design a function that, when revolved, produces an aesthetically pleasing drinking glass. Several of the labs also ask the students to supply proofs to theorems motivated by the lab's topics.

The presentation will include examples of labs used in our course, an introductory *Maple* manual written for our students, and material on a *Maple* package primarily for vector calculus that we have written.

Materials Development for an Advanced Mathematics Computing Laboratory

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Resource materials for use in abstract algebra are being developed to support a mathematics computing laboratory. The materials and the laboratory allow the integration of high- level computing into advanced mathematics courses; courses, which to date, have felt very little of the benefits of computing. The materials are used as teaching and learning aids, exploiting the power of computing to give students a new perspective on traditional topics.

An Undergraduate Center for Applied Mathematics

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This ILI project supported the development of an undergraduate Center for Applied Mathematics (ICAM) within the Department of Mathematics at the University of St. Thomas. Through the CAM, existing courses in applicable mathematics, including courses in calculus, linear algebra, differential equations, numerical analysis, and dynamical systems, can address more realistic problems and take advantage of the Center's array of computer resources selected for their versatility, their accessibility, and their effectiveness in approaching applied problems. In addition, an exciting new course, "Applied Mathematics and Modeling," has been added to the Department's offerings. The new course involves teams of students, working under the direction of a faculty advisor, on problems which have been recruited from industry, business, and government.

Through an endowment provided by the host institution, the Center is staffed by a full-time Director who is a member of the Mathematics faculty. The Center also benefits from the expertise of an External Advisory Committee consisting of applied mathematicians and users of applied mathematics in a variety of industries. Among the problems tackled thus far by teams of students working in the Center are 1) modeling dynamic stresses in an angioplasty catheter for a large biomedical company, 2) development of a loss reserve model for a regional life insurance company, and 3) the analysis of vessel traffic control strategies for restricted waterways.

Among the hardware provided through the ILI Program (with matching contributions provided by the institution) are Sun Sparcstations, NeXT, Macintosh, and PC-compatible computers, along with a sophisticated networking capability. A few of the software packages which run on the CAM network are APL+, C++, MATLAB, *Mathematica*, *Phaser*, and some mathematical/scientific documentation packages. One of the goals of the Center is the promotion of careful written and oral presentation of findings by student teams.

Through work on meaningful mathematical problems from business and industry, we expect our students to develop a better appreciation for the vital and fascinating role played by mathematics in the real world. The ultimate goal of the Center is the placement of graduates well-versed in applications of mathematics and experienced in creative problem-formulation and problem-solving processes.

Classroom Equipment for Instructional Enhancement of a Computer/Math Core Course

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Core Studies 5 is a 3-hour, 3-credit course entitled "Introduction to Mathematical Reasoning and Computer Programming." It was designed jointly by the Department of Mathematics and the Department of Computer and Information Science and is aimed at non-mathematics, non-computer science, and in general, non-science majors.

The course introduces such students to mathematical concepts and reasoning and it provides them with hands-on programming experience to aid in understanding the nature and power of the modern computer. This course is required of all undergraduate students, with the exception of those who have taken more advanced courses in both mathematics and computer science.

This paper discusses a project under which the Core Studies 5 classrooms were re-equipped. The project was designed in order to improve the instructional quality of the course and give students experience with state-of-the-art computer equipment. Two classrooms designated for Core Studies 5 were equipped with video projectors hard-wired to computer workstations. Two additional rooms were set up as "computer classrooms" with student workstations connected through a local area network. Our choice of equipment was influenced by the requirements of the course and by budget constraints.

The initial results of this project have been encouraging. The instructors have been using the projectors and computers to illustrate many of the topics taught in the lectures. We feel that it is especially important for non-mathematics, non-computer science students to participate in such demonstrations in class and to become acquainted with modern technology in order to reduce their mathematics and computer science anxiety. Our hope is that this project will lead to still further enhancements in the instruction of this course.

The Collaborative Computer Calculus Portfolio Program at Manhattan Community College

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The purpose of our calculus portfolio program is to improve success and retention in calculus for BMCC's population which is two-thirds women, and eighty-five percent African-American and Latino. Our calculus program emphasizes student collaborative projects, and uses Apple IIe, Macintosh and IBM PC's, and varied software including *Maple*, *Derive*, and *True Basic Calculus*. A laboratory technician introduces the students to the software, and supports them with their projects, so even students of less computer literate faculty benefit from this program. Students working in groups use computer graphers and computer algebra systems to create written projects. The students turn these collaborative projects into individual portfolios by selecting their three favorite projects and writing an essay that explains why they selected these projects, how the technology helped each project, and how each project helped their understanding of calculus. The desktop publishing software connected to these systems allow student reports to look extremely professional. Our experience verifies David Smith's results at Duke University. When students are capable of more professional looking output, they spend more time making the content equally professional.

This effect was clearly shown when one of our African-American female students interviewed at a local Ivy League university. The first reaction was that she had a community college calculus course, and thus probably needed remediation. She then showed her set of calculus projects developed through our program. Other professors were called in to look at her work. She ended the interview with a scholarship. Our project produces students capable of high level calculus performance.

Results of the Program: In the first semester in which we introduced collaborative computer calculus projects, our passing rate went from fifty-eight to seventy-two percent. In this group the number of students persisting through Calculus III tripled.

Scientific Computation Laboratory at Hofstra University

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We have developed a scientific computation laboratory targeted at undergraduate research and coursework in mathematical dynamics. The Laboratory consists of Macintosh (4 Mac IIsi) and DOS-based (3 Compaq 486/50) computers, together with Apple and IBM laser printers and communications to the University VAX cluster. Software includes programming languages (Basic, C, Pascal), specialized applications to fractals and graphics, and word-processing software.

Mathematical dynamics played a central role in Hastings's computer graphics class in the spring of 1992. In particular, students studied planetary dynamics and stability through simulation and computer graphics. This project resulted in a computer satellite-docking game.

Three MS theses related to dynamics have also been completed under Hastings and Weiss, and a fourth is in progress.

The laboratory has become a focal point for our best majors. In the next year, Hastings and Weiss will offer a team-taught course in dynamics and fractals and Weiss will teach a two-semester undergraduate course in dynamics. The group will also offer a lecture series and laboratory based exercises in "mathematics as an experimental science" to our own students and those in area high schools.

Calculus-Differential Equations Sequence

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The NSF–ILI grant at the Rochester Institute of Technology has helped to fund a Macintosh laboratory for students principally enrolled in Multivariable Calculus and Differential Equations. However, some pilot sections of the first-year calculus sequence as well as classes in boundary value problems and numerical methods have also begun to use the laboratory facilities. Most of the students' projects use *Mathematica*, but *Tools for Exploring Math* is also available for use in the first-year sequence.

The grant assisted with the purchase of 21 Macintosh IISI's with color monitors, increased memory, and enhanced *Mathematica 2.1*. The equipment is supplemented with 13 Macintosh SE's equipped with the *Mathematica* front end that access the *Mathematica* kernel that runs on DEC workstations. Two laser writers and an image writer are also available. The grant project is assisted by the use of a specially equipped classroom for demonstrations and classroom interactions.

Student assignments are designed to enhance the calculus sequence. A few of the assignments are projects using slopefields, numerical and graphical analysis of solutions of differential equations, applications in mechanical and electrical vibrations, 3-dimensional surface exploration, investigation of series convergence, and numerical and graphical introductions to concepts such as derivatives and integrals.

Improvement of Calculus Laboratory and Extension of Laboratory Concept

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The first-year calculus courses at Siena College have been taught using three lectures and one two-hour laboratory period weekly since 1988. Laboratory exercises were written to develop an understanding of the underlying mathematical concepts, to elaborate on topics covered in lecture, and to do mathematics not normally associated with the calculus. The College provided five Macintosh computers and the Computer Algebra System (CAS), *Mathematica*, to support a section of 24 students. Our grant proposal requested funds to expand the laboratory to 12 computers, each with the CAS installed. Half of our laboratory exercises now have formal computer "notebooks" to supplement the description of the experiment; most are more easily done using the computer. The expanded laboratory has had the anticipated effect of generating requirements for use from courses other than calculus. At this time our upper-level course in applied mathematics performs the majority of its homework and takes all examinations using the laboratory equipment. Our courses in linear algebra and introductory differential equations have several requirements each semester which can only be done with computers. The calculus laboratory has become a campus-wide experiment in the use of computer networks to provide access to many instructional packages from one location. This happened because we received a grant from Wolfram Research, Inc., through their Educational Grant Program. We have found that the demand for access to the laboratory exceeds the available time for scheduling. The ILI grant has enhanced mathematics instruction at Siena College at all levels of study. Now we are searching for funding to create a second similar laboratory.

A Laboratory Course in Mathematics for Liberal Arts Students

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A project funded in part by the ILI Program of the NSF. The Department of Mathematical Sciences at Appalachian State University offers a laboratory-based liberal arts course entitled Math 1010—Introduction to Mathematics. This course is designed to meet the core mathematics requirement for non-science and non-business majors by introducing them to applications encountered in realistic decision making. Emphasis is placed on showing students how to apply previously learned mathematical skills and how to communicate their results in writing. Current target application areas are resource allocation; banking, credit, and financial planning; measurement and triangulation; collection, organization, and elementary analysis of data.

The laboratories are designed to give students an intuitive understanding of mathematical concepts. The projects allow students to use real data, often personally gathered or suggested. Students work individually and in groups employing various computer software packages and equipment to investigate

the behavior of the models they create. The packages are chosen primarily for their predominance in the workplace whenever possible (e.g., the spreadsheet *Lotus 1-2-3*). To complete a lab assignment, students write lab reports using a word processor and incorporating output from the packages, targeting their reports to various audiences (e.g., an employer, peer, or the general public).

Non-laboratory class time is usually used for review of necessary algebraic properties, demonstration of equipment or software, and class discussion. Occasionally, formal lectures are given on non-prerequisite topics such as bias in data collection, linear programming, and right triangle trigonometry.

Preliminary feedback indicates that students are much more confident (and vocal!) about their solution and their approach, taking pride in ownership. In general they feel that while Math 1010 did not make math more enjoyable, they appreciate the value and usefulness of their mathematical knowledge.

A Laboratory for Computer Aided Exploration of Concepts in Calculus

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The East Carolina University Mathematics Department has begun a technological reform of the calculus curriculum. This effort is supported by a National Science Foundation Instrument and Laboratory Improvement Grant (USEME-9151209) and several East Carolina University Student Technology grants.

The approach is laboratory based, with students working in lab teams of two. They engage in physical and mathematical experimentation, computation, discovery, and supplemental work. Lectures rely on computer presentations and applications. The curriculum has been modified to reflect this new approach and potential. Modifications include: exposure to *Mathcad*, *Derive*, and *Microsoft Word*; inclusion of such topics as Euler's method, discrete optimization, and numerical approaches to natural logarithm; reordering of the presentation of such topics as sequences, partitions, area, and the Fundamental Theorem of Calculus; and incorporation of graphical approaches to sequences, series, and power series.

The implementation is in three areas. We have set up 1) several sections of computer enhanced calculus using our own lab materials and a standard calculus text (with reordering of some topics and insertion of new topics); 2) a section of Duke University's Project CALC, designed by David Smith and Lang Moore; we plan to install 3) a section of enhanced calculus for local high school students to take at the university.

The physical facilities include a computer laboratory equipped with 20 IBM PS2 personal computers, 2 printers, a file server, 2 portable computers for lectures, and 2 developmental computers. The software includes *Mathcad* for numerics and spreadsheets, *Derive* for symbolic manipulations and graphing, *Microsoft Word* for word processing, and *Mathematica* for upper-level usage.

The generation of local funding was accomplished by a university wide computer usage fee of $25 per semester per student. Our administration then uses these resources in support of computer enhancement via Student Technology grants.

Computer Laboratory for Teaching Fellows

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Using funds from an NSF–ILI grant, I have designed a one-credit, two-hour, Computer Laboratory for students in first- and second-semester calculus. The students work in teams of two which pair a first-semester calculus student with a second-semester calculus student. The Calculus I students felt free to ask their teammate what might seem to be stupid questions. While explaining the material, the Calculus II students greatly enhanced their own understanding of the concepts.

Each topic was covered in-depth by two labs one week apart. At the first session, the teams plot graphs, generate numerical data, color and annotate their print-outs. As they color the graphs and write up their analysis and observations on the print-outs, they are lead to a deeper understanding of the material; they cannot simply rely on the computer as a black box. The teams turn in their annotated printouts as a first draft which I grade, correcting any misconceptions, and suggesting other examples to try. The students spend the first part of the second lab refining their experiments. Then they write a polished report, using a mathematical word processor.

This course combines the experiment-conjecture method of learning mathematics, a cooperative and integrated learning environment, writing across the curriculum, and the double submission method.

Wright State University Calculus Laboratory Project

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Objectives: The goals of this project are to improve Calculus instruction by

(i) providing a student-oriented interactive learning environment that is conducive to experimentation and cooperative learning.

(ii) giving more emphasis to concepts and problem solving and less to symbolic manipulation.
(iii) emphasizing verbal and written communication of mathematics.
(iv) providing exposure to the kind of technology students are likely to be using in a technical career in the 21st century, and training in appropriate use of this technology.

Description: A computer laboratory can help accomplish each of these objectives. Traditional Calculus at Wright State is taught with 5 hours of lecture per week. Students in laboratory sections have 4 hours of lecture and 2 hours lab, or 3 hours lecture and 3 hours lab. In addition there are open lab hours when students can work on assignments not completed during scheduled laboratory classes.

Students know that in any laboratory they will be doing something rather than listening. In our Calculus laboratory, students use *Mathematica* software, a powerful computational and graphics tool that allows instructors to write an interactive text. The notebooks students work with contain narrative, interactive examples, and problems. They can work the problems in the same notebook by entering and executing their own commands. The role of the instructor in the laboratory is to provide assistance and guidance. Graduate teaching assistants and undergraduate lab assistants provide additional help during laboratory classes and staff open lab hours. Because students are required to work in pairs, they must discuss what is happening with their lab partner. They are required to submit lab reports in standard written English. Hence our students do far more talking and writing about mathematics than traditional calculus students. Because *Mathematica* is capable of extensive numeric and symbolic computation, or creating complex color graphics in seconds, students can concentrate more on concepts and problem solving, and less on lengthy hand calculations.

Background: This project has been under way since spring quarter of 1991, and has received substantial funding from the National Science Foundation: a two-year grant for Curriculum Development (awarded August 1991), and a grant for Laboratory Improvement (awarded June 1992). The latter grant was matched by university funds, which allowed us to acquire one of the best-equipped mathematics laboratories in the nation, with 21 networked NeXT color workstations.

Plans: We are now at the end of the experimental stage and working for wider participation. We plan to offer thirteen sections of calculus using the laboratory during the calendar year 1993, and to move toward using the laboratory in all sections in the not-too-distant future.

Comparative Studies on the Use of Computer Algebra Systems in the Teaching and Learning of Undergraduate Mathematics

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Through a joint grant from the National Science Foundation and Portland State University, the Department of Mathematical Sciences is investigating the use of Computer Mathematics Systems in Engineering Calculus. Four faculty members, Paul Latiolais, Jeanette Palmiter, Dan Streeter, and Dorothy Williams, are using four different types of technology: *Derive*, *Maple*, HP-48SX, and TI-81 to teach four comparable classes of calculus. The project's goal is to help determine answers to the questions: 1) Which of the four popular types of computer software and calculators for calculus is preferred by students, is preferred by faculty, and contributes most to understanding of calculus? 2) How are the students using the technology? What type of backgrounds are needed as pre-requisites to succeed in a technology-enriched classroom? How much time should be spent in the lab and how much time is best spent in the classroom?

Although no results are yet available, preliminary data indicates that students frequently access the graphing and numerical features and rarely use the symbolic capabilities of the systems, even when symbolics are called for in a problem. If this trend continues into the subsequent quarters, there may be strong indications that the less-expensive and easy to use TI-81 graphics calculator may be best suited.

The Project began in Fall 1992 and will continue through 1994.

A New Approach for Teaching Mathematics Courses in a Computerized Classroom

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College Misericordia is a co-educational liberal arts college. Students take two mathematics courses as a part of the core. We offer discrete mathematics as a core course which enrolls about 120 students per year and use an innovative approach developed by Ed Dubinsky and Nancy Baxter to teach/learn it. The method uses the mathematical programming language *ISETL* (Interactive SET Language) as a main tool and a cooperative learning approach. Currently Mazen Shahin is writing an interactive workshop on discrete mathematics (workbook) in consultation with Nancy Baxter of Dickinson College.

The title of the workshop is "Introduction to Discrete Mathematics: An Interactive Approach with *ISETL*." The workshop utilizes pedagogical issues, constructivist approach, and uses *ISETL*. Each section of the notes starts with

carefully designed computer activities to introduce the concepts to the students in an intuitive way. The students are required to do activities before the discussion in the class. The approach used is a hands-on approach instead of the traditional lecture approach. Classes meet in the College Academic Computer Lab, where each student has access to a microcomputer. Students work in groups of three or four. The main benefit to this approach is that the programming process in *ISETL* helps students to make mental constructions to handle mathematical ideas, and leads to thinking about mathematics in an independent manner.

We also use a new approach for teaching calculus which was developed by Ed Dubinsky and Keith Schwingendorf of Purdue University and was funded by the NSF. This approach uses *ISETL* and the symbolic computer system *Derive* and emphasizes cooperative learning and a minimum amount of lecturing. We use the Purdue Calculus package which include the textbook *Calculus, Concepts and Computers.* In a pilot design of this approach at Misericordia, we assigned three hours of class for the three-credit calculus course and scheduled two one-hour labs. Each year we have two sections of Calculus I, three sections of Calculus II, and one section of Calculus III.

We are using a preliminary developed material of a new approach for learning and teaching linear algebra. This approach is being developed by Donald Muench of St. John Fisher College and Mazen Shahin. This approach uses *ISETL* as a main tool, and rests on the research on how students learn abstract mathematical concepts. By doing carefully prepared exercises and computer activities, students will be helped to construct in their own mind the major concepts and algorithms of linear algebra. The linear algebra is turned to be a laboratory course.

Microcomputer-Equipped Workshops for the Introductory Mathematics Program

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Overview of Program

The Introductory Mathematics Program at Dickinson College involves the development of six new introductory mathematics courses—Quantitative Reasoning, Statistics with Application, Calculus with Applications I & II, and Calculus I & II. These courses provide students with multiple entry points into the study of mathematics and a gateway into the mathematics major.

In the workshop approach, lectures are replaced by interactive teaching. All classes are held in micro-computer equipped classrooms/laboratories funded by an equipment grant from the National Science Foundation. In the workshop environment, students learn by doing and then reflecting on what they have done. Lectures are replaced by classroom discussions. These discussions are meaningful to the students, since they relate directly to what the students have already done.

Description of Courses

Workshop on Quantitative Reasoning is designed to help the general student acquire fundamental skills and understand basic ideas of numerical arguments, such as understanding scales and magnitudes, interpreting graphs and tables, appreciating randomness, and drawing inferences from data.

Workshop Statistics with Applications is designed for students majoring in the social sciences who plan to take subsequent quantitative courses in their major fields of study. The data-centered introductory course concentrates on the application of statistical concepts and reasoning—rather than rote numerical computations—to genuine data.

Workshop Calculus with Applications I & II is designed for students who need to acquire fundamental concepts in discrete mathematics and calculus, but who are not prepared to enter Calculus I. The emphasis on applications not only enables students to use calculus in other disciplines, but also enhances motivation. A variety of software tools are used, including a spreadsheet package, a computer algebra system, and *ISETL*.

Calculus I & II is designed to prepare students for further study in mathematics. *Mathematica* is used to help them develop a firm conceptual understanding of fundamental ideas such as limit, derivative, and definite integral.

Instructional Materials

In the four Workshop courses, students work together on tasks in Student Activity Guides, a collection of guided inquiry notes presented in a workbook form. The tasks in the Guides are designed to help students explore the behavior of mathematical systems in much the same way that science students explore natural phenomena. They make predictions, enter observations, and do calculations directly in their guides. These Guides are written flexibly in order to be used with most standard software packages.

In the Calculus I & II laboratories, students work through *Mathematica* notebooks designed to help them experiment with and explore further concepts presented in lecture. *Mathematica* demonstrations are also incorporated into the lecture portion of the courses.

Development of curricular materials for the new Introductory Mathematics Program is supported by grants from the Fund for the Improvement of Post-Secondary Education (FIPSE) and the Knight Foundation. Sample materials will be available at the poster session.

Animated Graphics: Interpreting Solutions to Numerical Models on Supercomputers

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Supercomputers have become prevalent in scientific computing, yet few undergraduate students are exposed to the typical supercomputer environment. The Department of Mathematics at Indiana University of Pennsylvania (IUP) has offered a remedy to this situation by introducing the course Numerical Methods for Supercomputers. Students learn to design programs that exploit vector and parallel architectures, they submit jobs to the Pittsburgh Supercomputing Center's (PSC) Cray YMP, and at their home site they synthesize large quantities of output data into an animated graphical display. Smooth animations require the speed of workstations. This grant provided for a network of five DECstations, so that students can learn to use scientific visualization in problem-solving.

The special topics course, Numerical Methods for Supercomputers, was taught using the funded DECstations for the first time in Spring 1992. Students had computer accounts on IUP's DECstations and Vax Cluster, and on the PSC's DECstations, Vaxes, and Cray YMP. Students used the DECstations' windowing, networking, and multi-tasking capabilities to freely work on several of these computers simultaneously.

In three of the students' assignments, they generated animated graphical output from their numerical results. In order to become familiar with the process, the first graphics assignment required only that the students run a program that the instructor had written and generate the necessary graphical output. In the second assignment students used numerical integration to simulate the carburization process—carbon diffusing through an iron rod—and then animated the diffusion process, with color representing concentration of carbon. In the third assignment, students numerically approximated the solution to the Poisson equation to model the temperature distribution in a rectangular steel plate. From the numerical temperature distribution, they created a color contour plot, with color representing temperature. Several of the students also animated the iterative scheme for solving the system of linear equations.

The principal investigator is eager to share ideas with others. He can be contacted at the above address or by sending electronic mail.

A Mathematica *Laboratory for Calculus: Understanding Through Exploration*

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At Lafayette College, we have integrated a computer laboratory experience into our three-semester calculus sequence for students of engineering and the mathematical and physical sciences. Meeting in weekly laboratory sessions, students use *Mathematica* to anticipate new ideas and to investigate in greater depth ideas to which they have ben introduced in the classroom. Laboratory activities are designed to help students learn to combine effectively the use of graphical, numerical, and symbolic techniques in solving problems and investigating mathematical ideas, to increase students' sense of ownership of mathematical ideas by providing opportunities for exploration and discovery, and to encourage students to develop collaborative learning skills. In addition, the laboratory experience helps our students to acquire a working knowledge of a computational tool which can be of great value to them in their future work in mathematics, science, and engineering.

Our laboratory project began with pilot sections of Calculus I and II in academic year 1990–91; full implementation of the laboratory experience in the three-semester sequence was completed in 1991–92 when there were more than 450 registrations in the affected courses. In 1992–93, all sections of the calculus sequence will include laboratory experiences and the total enrollment in those sections will be approximately 600. In addition, by the end of the fall semester of 1992, all eighteen faculty members in the department will have taught laboratory-enhanced calculus courses. Students in intermediate and advanced courses in linear algebra, differential equations, and numerical analysis are already making extensive use of *Mathematica* in their studies and further expansion of these efforts is anticipated. In addition, we have held workshops for our faculty colleagues in engineering and the sciences to encourage them to take advantage of the laboratory experience that their students are having in calculus.

Improving Instruction for Pre-Service and Inservice Elementary and Secondary Mathematics Teachers

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The goal of this project is to improve mathematics instruction for pre-service and in-service mathematics teachers through the provision of a networked computer laboratory. By focusing on teaching mathematical content using interactive

computer technology, the project will prepare teachers to effectively teach mathematical concepts using that same technology as they enter the classrooms of the future. The interactive capability allows the instructor to interact with students through the network in whole group, small group, or individual instruction. The computer laboratory will allow both pre-service and in-service, elementary and secondary teachers of mathematics to use computer technology to more effectively develop mathematical concepts, make generalizations, solve problems in mathematics, promote their student's discovery learning of mathematics. In particular, our students will be better prepared to teach mathematics as a result of this project because of the innovative, efficient means of developing mathematical ideas that an appropriately run computer environment can offer.

Under the direction of the chair, Dr. Stanley G. Wayment, the Department of Mathematics has built a Mathematics Education Laboratory. The department has allocated two large classrooms for the construction of the lab. An office has been constructed adjacent to both classrooms. NSF ILI Grant USE-9251955, "Improving Instruction for Pre-Service and In-Service Elementary and Secondary Mathematics Teachers," is directed by Paul Kennedy as PI, Sharon Gronberg and Kevin Jones as co-PI's. This grant was used to set up two computer classrooms: one with 20 Apple II computers which SWT had purchased a few years ago, and the other with 20 new Mac IIsi computers, network software, and the necessary projection equipment for both classrooms. The grant also provided funds to purchase lab packs or network copies of educational software appropriate for pre-service elementary teachers as well as for the pre-service secondary mathematics teachers. As part of the grant agreement with NSF, the co-PIs are to develop appropriate curricula in which the students use the computers in a classroom setting and for laboratory assignments. These two rooms are the classrooms for pre-service teaching students. In addition, the laboratory will be made available for regular mathematics instruction as time and space permits, and will be used in summer, weekends, or evenings to conduct in-service training for current elementary and secondary teachers.

The curriculum developed for the computer network will be available for use at other sites, ensuring the replicatability of the project. Because of its innovative nature, the project will serve as a model for other institutions of higher education and for public schools in Texas and across the country. By coupling interactive computer technology with cooperative learning in this project we will enhance the mathematics learning of the thousands of SWT elementary and secondary mathematics students and the hundreds of thousands of students they teach in the future.

Computer Laboratory Enhancement of Discovery in Calculus

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We propose to implement a computer laboratory that will strengthen the discovery and exploratory components of the first year of calculus by providing power, flexibility, vividness, and transparency to the general user. The laboratory will permit students to manipulate and experiment with calculus concepts both theoretical and applied. The goal of the program is to improve greatly the education provided to calculus students by acquainting them with the mathematical ideas that are more accessible through the symbolics, numerics, graphics, and programming capabilities of computer algebra systems. Deeper understanding, retention, and excitement in mathematics is our goal.

A Mathematical Laboratory for Numerical, Symbolic and Graphical Computing

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Students are focusing more on concepts in a computer laboratory that supports numerical, symbolic and graphical calculations. The laboratory consists of 15 NeXT personal workstations, supported by networked fileservers and laser printers. A laboratory experience is being incorporated into six mathematics and mathematics education courses.

A Technology Based Algebra Course

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This is a pilot project funded under the Leadership in Laboratory Development section of ILI. It is an effort to test whether the pervasive use of a graphing calculator in a revised intermediate algebra course can significantly increase the number of women and minorities who choose to study Precalculus and Calculus.

Students use TI-81 calculators in exploratory laboratory projects. The new curriculum presents algebra in the integrated context of graphs and functions. It emphasizes the development of "real-world" mathematical models and their subsequent analysis, graphically and numerically as well as symbolically. Core topics have been identified and the material unified around these central themes.

A Computer-Based Calculus Laboratory

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Many instructors across the country now incorporate computers into their calculus courses or offer a separate laboratory session as part of the course, typically 50 to 90 minutes long. Often the students will work independently on homework problems and laboratory exercises using a computer algebra system (CAS).

At Whitman we have been teaching a laboratory that is modeled on the traditional science laboratories in physics, chemistry, and biology. The long (3-hour) laboratory period allows students to work on problems in substantially more detail and depth than is usually possible in a calculus course. Computer software handles most of the computational tasks, so the students can spend more of their time on conceptual problems or setting up the problems for mathematical analysis.

Our laboratory exercises are designed to improve understanding of important concepts and to provide an introduction to mathematical modeling. Written reports on each exercise emphasize clarity and style as well as content. Indeed, teaching the students to write clearly about technical topics is a major goal of the laboratory course. This is a skill which students do not currently acquire in any formal or guided way. If they develop this skill early it will enhance their entire education.

Students are allowed to use any word processor, but many of them choose to use TEX , even though the VAX implementation of TEX is somewhat cumbersome. A locally written, eight-page introduction to TEX , together with a small collection of 'lab report' macros, provides enough support for most students to use TEX successfully.

The facilities we currently use are barely adequate to the task and inconvenient to use. Our National Science Foundation ILI grant will provide $65,000 to improve our equipment. We will equip the laboratory with 10 Apple Macintosh computers, a file and print server, and a printer. These microcomputers will be powerful enough to run the computer algebra system *Maple* instead of the more primitive software now in use. The Macs will also provide a much nicer environment for TEX ; we hope more students will elect to use TEX as a result.

Using Computer Algebra Systems from College Algebra through Differential Equations

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The University of Wisconsin Center–Fox Valley is a two-year liberal arts transfer campus of the U.W. system, with about 1,500 students. The courses primarily affected by the grant are College Algebra, Trigonometry, Calculus I, II, and III, and Differential Equations.

The grant has enabled us to outfit a mathematics laboratory with computers, to have computers to take into the classroom, and to buy several additional copies of *Derive* to make it available over the campus network to all who need it. Our plans are to buy a printer for mathlab soon and to buy a few copies of either *Maple* or *Mathematica* for use in our advanced classes.

This equipment and software has enabled us to use *Derive* in all the classes mentioned above. It has also made it easier to use computers in some other classes such as statistics and business calculus.

Since we are a transfer campus our math program is, of necessity, rather conventional. We use Thomas and Finney in Calculus, and similar traditional texts in College Algebra and Trigonometry. While we await books we are satisfied with which integrate use of computer algebra systems more thoroughly into these courses, we make our own materials and adapt those which others have developed. We are trying to work the use of a CAS into each course, starting with the most appropriate topics and/or best opportunities. As our experience increases we will do a lot more.

Every section of the pre-calculus and calculus courses has had an introduction to *Derive*. In most there have also been lab assignments, group projects, and/or short daily assignments. The presentation will go into more detail about what we have been able to do and what we expect to do in the future.

FY 90–92 NSF Division of Undergraduate Education ILI/LLD Awards in Mathematics

ENTERPRISE STATE JUNIOR COLLEGE, Enterprise, AL; *Improvement of Instructional Resources in Mathematics*; PI: Wanda M. Motes; #9151572.

JOHN C. CALHOUN STATE COMMUNITY COLLEGE, Decatur, AL; *Improvement of Instructional Resources in Mathematics*; PI: Suzanne B. Joiner; #9151614.

LIVINGSTON UNIVERSITY, Livingston, AL; *Initial Equipment for a Mathematics Laboratory*; PI: Julia E. Massey; #9050638.

UNIVERSITY OF SOUTH ALABAMA, Mobile, AL; *Mathematics Workstations in a Laboratory Environment*; PI: John E. Cruthirds; #9151599.

ARIZONA STATE UNIVERSITY, Tempe, AZ; *Computer Laboratory Classroom for Undergraduate Mathematics Curriculum*; PI: Joaquin Bustoz; #9251008.

NORTHERN ARIZONA UNIVERSITY, Flagstaff, AZ; *Capstone Experiences for Mathematics Majors*; PI: John W. Hagood; #9051163.

CALIFORNIA POLYTECHNIC STATE UNIVERSITY, San Luis Obispo, CA; *Computer Laboratory for Mainstream Calculus*; PI: Donald G. Hartig; #9151121.

CALIFORNIA POLYTECHNIC STATE UNIVERSITY, San Luis Obispo, CA; *Creation of Videodiscs to Enhance Instruction in Mathematics*; PI: Rex L. Hutton; #9250287.

CALIFORNIA STATE UNIVERSITY, Chico, CA; *A Pilot Program for Computer Aided Instruction in Mathematics*; PI: LaDawn Haws; #9051194.

CALIFORNIA STATE UNIVERSITY, Fresno, CA; *Calculus, Computers, and Mathematica*; PI: Larry W. Cusick; #9251702.

CALIFORNIA STATE UNIVERSITY, Hayward, CA; *Interactive Mathematics Classroom*; PI: Marvin R. Winzenread; #9252126.

GOLDEN WEST COLLEGE, Huntington Beach, CA; *Improving Precalculus and Calculus Instruction Using Mathematica*; PI: John H. Wadhams; #9051185.

HUMBOLDT STATE UNIVERSITY, Arcata, CA; *Exploration in a Laboratory Setting with the Calculus Companion*; PI: Diane L. Johnson; #9250334.

LOYOLA MARYMOUNT UNIVERSITY, Los Angeles, CA; *Mathematics Using Mathematica*; PI: Thomas M. Zachariah; #9250735.

PITZER COLLEGE, Claremont, CA; *Computer Classroom for Liberal Arts Mathematics Curriculum*; PI: Jim E. Hoste; #9250512.

SAN FRANCISCO STATE UNIVERSITY, San Francisco, CA; *Laboratory Enhancement for Applied Mathematics*; PI: David M. Ellis; #9251673.

SAN JOSE STATE UNIVERSITY, San Jose, CA; *A Computer Laboratory for Learning Algebra, Trigonometry and Calculus*; PI: Michael J. Beeson; #9050894.

UNIVERSITY OF CALIFORNIA, Berkeley, CA; *Developing Statistical Understanding Through Interactive Computing/Graphics*; PI: Leo Breiman; #9251786.

COLORADO SCHOOL OF MINES, Golden, CO; *Toward Making Mathematics a Laboratory Science*; PI: Frank G. Hagin; #9152615.

FORT LEWIS COLLEGE, Durango, CO; *Introducing Computer Technology in Mathematics Teacher Training Programs*; PI: Annette J. Cooper; #9152866.

METROPOLITAN STATE COLLEGE, Denver, CO; *Integrating Mathematica into a Reformed Calculus Curriculum*; PI: William D. Emerson; #9251597.

UNIVERSITY OF NORTHERN COLORADO, Greeley, CO; *Adding A Computer Laboratory Component in the Math and Physics Curriculum*; PI: Christopher S. Cotter; #9250882.

UNIVERSITY OF SOUTHERN COLORADO, Pueblo, CO; *A Mathematics Resource Center for Senior Research Projects*; PI: Paul Chacon; #9250602.

UNIVERSITY OF DELAWARE, Newark, DE; *Undergraduate Mathematics: Technology to Improve Student Capabilities*; PI: John G. Bergman; #9251602.

AMERICAN UNIVERSITY, Washington, DC; *The Incorporation of Interdisciplinary Strategies in an Undergraduate Mathematics Course at The American University*; PI: Virginia Stallings-Roberts; #9152401.

MATHEMATICAL ASSOCIATION OF AMERICA, Washington, DC; *Establishing Regional Sites for the Dissemination of Computer Based Laboratory Materials in Mathematics*; PI: Gerald J. Porter; #9150272.

MATHEMATICAL ASSOCIATION OF AMERICA, Washington, DC; *Interactive Mathematics Text Developers Conferences*; PI: Gerald J. Porter; #9251037.

UNIVERSITY OF THE DISTRICT OF COLUMBIA, Washington, DC; *Computers for the Calculus: An Interactive Laboratory Approach*; PI: Abdollah Darai; #9151711.

GEORGIA SOUTHERN UNIVERSITY, Statesboro, GA; *Using a Computer Algebra System to Convert Calculus (and Related Courses) Into Formal Laboratory Courses*; PI: Arthur G. Sparks; #9052022.

SPELMAN COLLEGE, Atlanta, GA; *Electronic Classroom for Teaching Mathematics*; PI: Fred H. Bowers; #9152212.

UNIVERSITY OF GEORGIA, Athens, GA; *Calculus Workshop for Under-Represented Groups*; PI: Mary H. Dauenhauer; #9150989.

KNOX COLLEGE, Galesburg, IL; *Mathematica Notebooks for Calculus*; PI: Dennis M. Schneider; #9050757.

LAKE FOREST COLLEGE, Lake Forest, IL; *A Networked Computer Environment for Laboratory-Based Calculus*; PI: Edward W. Packel; #9151368.

NORTHWESTERN UNIVERSITY, Evanston, IL; *Experimental Mathematics Program*; PI: Robert R. Welland; #9151059.

WESTERN ILLINOIS UNIVERSITY, Macomb, IL; *CAS Equipped Classroom/Laboratory*; PI: Kent Harris; #9252288.

BALL STATE UNIVERSITY, Muncie, IN; *A Computer Laboratory Supporting Mathematica in a Revised Calculus Curriculum*; PI: Dale E. Umbach; #9151814.

BUTLER UNIVERSITY, Indianapolis, IN; *CalcLab: A What-if Classroom*; PI: Judith H. Morrel; #9151153.

FRANKLIN COLLEGE OF INDIANA, Franklin, IN; *Learning Mathematics with Computers*; PI: Richard M. Park; #9251727.

FRANKLIN COLLEGE OF INDIANA, Franklin, IN; *Computerization Across the Upper Level Mathematics Curriculum*; PI: G.Daniel Callon; #9251771.

PURDUE UNIVERSITY, West Lafayette, IN; *A Mathematics Laboratory with a Cooperative Learning Component*; PI: Keith E. Schwingendorf; #9252262.

ROSE-HULMAN INSTITUTE OF TECHNOLOGY, Terre Haute, IN; *Implementing an Upper-Division Mathematics Computer Classroom/Laboratory*; PI: Gary J. Sherman; #9150220.

ROSE-HULMAN INSTITUTE OF TECHNOLOGY, Terre Haute, IN; *An Upper-Division Mathematics Computer Classroom/Laboratory*; PI: Gary J. Sherman; #9151397.

TRI-STATE UNIVERSITY, Angola, IN; *Statistical Computing Laboratory*; PI: Dolores M. Tichenor; #9251042.

UNIVERSITY OF EVANSVILLE, Evansville, IN; *Computers in Calculus/Laboratory Classroom*; PI: Gene Bennett; #9250443.

IOWA STATE UNIVERSITY, Ames, IA; *Developing Modern Computing and Graphics-Based Methods for Teaching Important Concepts in Undergraduate Statistics Courses*; PI: William Q. Meeker Jr.; #9250829.

UNIVERSITY OF IOWA, Iowa City, IA; *Expanding Iowa's Model Calculus Materials to All Students*; PI: Keith D. Stroyan; #9250348.

UNIVERSITY OF KANSAS, Lawrence, KS; *Computer Aided Instruction of Undergraduate Differential Equations*; PI: Ralph Byers; #9250807.

MURRAY STATE UNIVERSITY, Murray, KY; *A Computer Laboratory for Calculus, Linear Algebra and Differential Equations*; PI: Robert H. Pervine; #9050464.

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FROSTBURG STATE UNIVERSITY, Frostburg, MD; *Computer Laboratories for a Restructured Calculus Curriculum*; PI: Marcelle Bessman; #9152702.

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COLLEGE OF THE HOLY CROSS, Worcester, MA; *Calculus, the Computer and the Mathematical Endeavor*; PI: Melvin C. Tews; #9051318.

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SAINT OLAF COLLEGE, Northfield, MN; *An Advanced Computing Laboratory for Undergraduate Mathematics*; PI: Arnold M. Ostebee; #9050637.

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UNIVERSITY OF MINNESOTA, Morris, MN; *Computer-Based Mathematical Experiments and Projects in Calculus*; PI: Michael F. O'Reilly; #9050797.

UNIVERSITY OF ST. THOMAS, Saint Paul, MN; *An Undergraduate Center for Applied Mathematics*; PI: John T. Kemper; #9050562.

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UNIVERSITY OF NEW MEXICO, Albuquerque, NM; *Pre-Calculus Instructional Computing Laboratory*; PI: Ronald M. Schrader; #9151691.

CUNY BOROUGH OF MANHATTAN COMMUNITY COLLEGE, New York, NY; *Collaborative Computer Calculus Laboratory Manual*; PI: Patricia R. Wilkinson; #9153712.

CUNY BOROUGH OF MANHATTAN COMMUNITY COLLEGE, New York, NY; *(PC)2: Personal Computers/Pre-Calculus*; PI: Patricia R. Wilkinson; #9250885.

CUNY BROOKLYN COLLEGE, New York, NY; *Classroom Equipment for Instructional Enhancement of a Mathematics/Computer Core Course*; PI: Chaya B. Gurwitz; #9051865.

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HOBART AND WILLIAM SMITH COLLEGES, Geneva, NY; *Macintosh Lab on Wheels*; PI: David J. Eck; #9151129.

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NORTH DAKOTA STATE UNIVERSITY, Fargo, ND; *Undergraduate Statistics Lab*; PI: Rhonda C. Magel; #9151551.

COLLEGE OF WOOSTER, Wooster, OH; *Symbolic and Graphing Technology and Cooperative Learning in Introductory College Mathematics at the College of Wooster*; PI: John R. Ramsay; #9151818.

OHIO STATE UNIVERSITY, Columbus, OH; *Calculus and Mathematica at the Ohio State University*; PI: William J. Davis; #9151945.

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HARRISBURG AREA COMMUNITY COLLEGE, Harrisburg, PA; *Mathematics Instruction Laboratory/Equipment*; PI: Oiyin P. Chow; #9250358.

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LAFAYETTE COLLEGE, Easton, PA; *A Mathematica Laboratory for Calculus: Understanding Through Exploration*; PI: L. Thomas Hill; #9152827.

MONTGOMERY COUNTY COMMUNITY COLLEGE, Blue Bell, PA; *Undergraduate Mathematics with a Laboratory Component*; PI: Roseanne S. Hofmann; #9151313.

SWARTHMORE COLLEGE, Swarthmore, PA; *A Mathematics Laboratory for First-Year Calculus*; PI: Charles M. Grinstead; #9152313.

UNIVERSITY OF PUERTO RICO, San Juan, PR; *A Computer Laboratory for Pre-Calculus and Calculus I at the College of Natural Sciences of the University of Puerto Rico – Rio Piedras Campus*; PI: Pablo M. Salzberg; #9251158.

UNIVERSITY OF SOUTH CAROLINA, Columbia, SC; *Undergraduate Statistics Computation Laboratory*; PI: John D. Spurrier; #9151052.

UNIVERSITY OF SOUTH CAROLINA, Columbia, SC; *Development of a Calculus Laboratory*; PI: Robert G. Phillips; #9250351.

CHRISTIAN BROTHERS UNIVERSITY, Memphis, TN; *A Computer Laboratory for Calculus*; PI: Arthur A. Yanushka; #9052185.

STATE TECHNICAL INSTITUTE, Memphis, TN; *Microcomputer Laboratory Project for Advanced Technical Mathematics Education and Certification*; PI: Robert O. Armstrong; #9050755.

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UNIVERSITY OF RICHMOND, Richmond, VA; *An Interactive Calculus Laboratory*; PI: John R. Hubbard; #9151767.

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WASHINGTON AND LEE UNIVERSITY, Lexington, VA; *Computer Laboratory for Advanced Calculus and Geometry*; PI: John L. Harer; #9250448.

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WHITMAN COLLEGE, Walla Walla, WA; *A Computer Based Calculus Laboratory*; PI: David R. Guichard; #9251348.

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