Foreword

The National Science Foundation Directorate for Education and Human Resources (EHR) is responsible for providing national leadership, examples of model programs, and support for enhancing the quality of education in science, mathematics, and engineering at all levels of the educational system. Within EHR, the Division of Undergraduate Education focuses on ensuring that the best possible undergraduate education is provided to meet the national need for high quality scientists, engineers, and mathematicians, dedicated and able teachers of precollege science and mathematics, and scientifically literate citizens.

The purpose of the Curriculum Development in Mathematics: Calculus Program is to support model projects which reform the calculus curriculum and instruction. The 82 projects described in this book were selected from the 311 proposals received in the first four years of the program. These projects were selected for their creativity, mathematical and educational quality, potential for utility at other institutions, and promise of having a national impact. Through the Calculus Program, NSF has provided a leadership role in responding to the clear need expressed within the mathematics community that the calculus curriculum and instruction must be improved.

Collectively, the projects in the book provide a great resource that should be of interest to science, mathematics, and engineering faculty at all colleges and universities.

Luther Williams
NSF Assistant Director
Directorate for Education
and Human Resources

Introduction

The **Curriculum Development in Mathematics: Calculus Program** is an integral part of the overall plan of the National Science Foundation to strengthen science, engineering, and mathematics throughout the United States. This publication describes the projects initiated during FY 88 through FY 91, the first four years of the NSF Calculus Program. It is hoped that this information will be useful to faculty, administrators, and others concerned about undergraduate mathematics education.

The program is managed by the Division of Undergraduate Education (DUE) with the cooperation of the Division of Mathematical Sciences (DMS). This partnership between DMS and DUE has greatly enhanced the management of the program and strengthened its impact. Most of the projects listed in this document were co-funded by DMS. In addition, several projects were co-funded by the Division of Elementary, Secondary and Informal Education; the Division of Research, Evaluation, and Dissemination.

The goal of the program has been to support projects that exhibit particular promise in contributing to the national effort to invigorate calculus instruction. Coordination with other disciplines in science and engineering and interactions among different sectors of the mathematical sciences community in the development of model curricula and prototypical instructional materials have been emphasized. The program has provided support for projects which deal with all the topics of a two-year calculus sequence, including linear algebra and differential equations. From an initial focus on planning projects and conferences, the scope of the program has expanded to include extensive and multi-year curriculum development projects. The use of technology has been integrated into curricula to varying degrees. The revitalized calculus courses typically place more responsibility on the students, whether learning through discovery, projects, or group interactions. Students are expected, in many projects, to communicate through written expositions, as well as orally. In-depth student projects which significantly model interesting applications are a central component in many courses.

As a result of these efforts, there has been considerable experience with renewing calculus curricula and instruction in diverse institutional settings. Thus, the stage has been set for large-scale implementation, involving students at both the collegiate and secondary levels. To impact significantly in the mathematics community, benefits are anticipated from forming regional and national consortia involving universities, two- and four-year colleges, and high schools. Important issues must be addressed in large-scale revitalization in order to effectively introduce the changes. Calculus also has a central role in the training of the next generation of high school and collegiate faculty, with graduate students frequently as instructors and prospective high school teachers as students. Through NSF and the calculus reform movement in general, efforts are underway to reinvigorate the learning of calculus throughout the educational system, developing dynamic curricula and instructional approaches in which instructors and students are continually challenged to think creatively.

The abstracts are divided according to the initial year of the award, and listed by state. Indicated for each project are the project director's name, institution, grant number, and amount of the award. For standard grants, the duration of the grant as awarded is given. For continuing year grants, the expected out year amounts are indicated. The out year commitments are contingent upon the availability of funds and progress of the project.

The following chart provides program submissions and funding data for the fiscal years 1988 through 1991.

($ Thousands)

	Number Proposals	Number Awards	FY88	FY89	FY90	FY91	FY92	FY93	Total
FY88	89	25	1,290	447	370	129	74		2,310
FY89	74	18		1,858	1,151	765	488	337	4,599
FY90	80	20			1,414	798	200		2,412
FY91	68	19				1,379	952	24	2,355
Totals	311	82	1,290	2,305	2,935	3,071	1,714	361	11,676

The title of the program has been changed to Curriculum Development in Mathematics: Calculus and the Bridge to Calculus, reflecting that the program has been broadened to include preparation for calculus and the interface between the senior year in high school and the freshman year in college. For further information about this program, please contact:

Division of Undergraduate Education
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550
(202) 357-7292

PROJECT ABSTRACTS: FY 1991 AWARDS

Calculus with Computers for the Mid-Sized University: Adapting and Testing the Iowa Materials

Steven C. Leth	Award No: USE 9153277
University of Northern Colorado	FY 91 $ 45,000
Greeley, CO 80639	FY 92 $ 20,000

The Iowa materials and approach to teaching calculus are being adapted, refined, and implemented throughout the calculus sequence. A lecture approach is being integrated with an interactive computer laboratory component centered around Mathematica Notebooks. Many of the students are future mathematics teachers.

Integration of Computing into Main-Track Calculus

James F. Hurley	Award No: USE 9153270
University of Connecticut	FY 91 $ 41,723
Storrs, CT 06268	FY 92 $ 79,907

The three-semester calculus sequence is being revised to integrate the computer as an active component of the learning process. A pilot program is being expanded throughout the three-semester sequence. A laboratory component is being introduced in which students will modify computer code written in True BASIC and apply the programs to a wide range of mathematical problems is being introduced.

Connecticut Calculus Consortium

Robert J. Decker	Award No: USE 9153298
University of Hartford	FY 91 $ 100,000
West Hartford, CT 06117	FY 92 $ 70,000

Students are introduced to realistic problems and to the technology (graphing calculators and microcomputers) that is capable of dealing with them. Existing materials are adapted and implemented on a state-wide basis. The laboratory materials and the text materials are integrated into the new course.

The Georgia Tech-Clemson Consortium for Undergraduate Mathematics in Science and Engineering

Alfred D. Andrew	Award No: USE 9153309
Georgia Tech Research Corporation	FY 91 $ 83,560
Georgia Institute of Technology	FY 92 $ 85,991
Atlanta, GA 30332	FY 93 $ 24,417

A large scale adaptation, refinement, and implementation project is invigorating the teaching and learning of calculus for science and engineering students. Innovations being adapted have been tested at the participating institutions. The three-year effort is taking advantage of both modern supercalculator and microcomputer technology and is incorporating group learning through team projects. The project will affect some 20,000 students over five years.

Multivariable Calculus Using Mathematica

Dennis M. Schneider	Award No: USE 9153249
Knox College	FY 91 $ 45,431
Galesburg, IL 61401	FY 92 $ 42,569

Computer technology is being exploited to produce a "leaner and livelier" multi-variable calculus curriculum supported by a collection of Mathematica Notebooks and graphics packages that provide material for classroom use as well as problems that invite students to explore further the concepts of calculus. A text is being produced which assumes that students have access to a powerful computing environment, but not necessarily Mathematica.

Disseminating Calculus in Context

James Callahan	Award No: USE 9153301
Five Colleges, Inc.	FY 91 $ 85,000
Amherst, MA 01002	FY 92 $ 120,000

The project is adapting and disseminating the Calculus in Context curriculum. The group of mathematicians with experience with this curriculum is being substantially expanded through intensive workshops, and materials are being prepared that allow instructors in high schools, two-year colleges, and four-year colleges and universities to teach the course without special training. Evaluation of the efficacy of the approach and of the dissemination efforts are part of the project.

Calculus in a Real and Complex World, Year II

Franklin A. Wattenberg	Award No: USE 9153266
University of Massachusetts	FY 91 $ 34,205
Amherst, MA 01003	FY 92 $ 29,562

A new, two-semester sequence is being developed which includes differential equations and linear algebra, and is based on the philosophy and spirit of the first-year calculus course developed under the Five Colleges Calculus in Context Project. Students gain a better grasp of the concepts of calculus when they are presented in the context of real and substantial applications that require a combination of techniques involving open-ended problems that often do not have clean, simple solutions. Writing and the use of computers are an integral part of this approach.

Calculus Reform at a Comprehensive State University with Project CALC

Charles C. Alexander	Award No: USE 9153283
University of Mississippi	FY 91 $ 60,000
University, MS 38677	12 months

The materials and approach to teaching calculus developed at Duke University are being adapted and implemented. The revised course emphasizes greater conceptual understanding through extensive writing, collaborative learning in a discovery-based microcomputer laboratory, and using mathematics for modeling real world phenomena.

Project to Adapt and Refine Purdue Model for Teaching Calculus for Liberal Arts and State Colleges

Carol L. Freeman	Award No: USE 9153259
Nebraska Wesleyan University	FY 91 $ 70,000
Lincoln, NE 68504	24 months

A consortium of institutions are adapting, refining, and implementing the approach to teaching calculus. Issues of computer anxiety and cooperative learning are being examined during the implementation phase. The adaptation phase includes introducing the use of graphing calculators.

Calculator Enhanced Instruction Project by a Consortium of NJ Community Colleges

Jean Lane	Award No: USE 9153258
Union County College	FY 91 $ 77,415
Cranford, NJ 07016	12 months

Five community colleges are adapting a calculator-based curriculum for calculus. Workshops are being conducted to introduce the faculty to the new curriculum and to begin its implementation. The faculty introduces the new approach to their colleagues as it is implemented in all calculus sections.

A Problem-Based Restructuring of Calculus

Jacob Barshay	Award No: USE 9153248
CUNY City College	FY 91 $ 55,000
New York, NY 10031	12 months

Students are working collaboratively in small teams under the guidance of advanced undergraduates on thought-provoking problems. The collection of problems is being expanded and includes materials for use with graphing calculators and guide books for the restructured course.

The Rensselaer-Albany Regional Calculus Consortium - A Curriculum Adaptation, Refinement, and Implementation Program

Timothy L. Lance	Award No: USE 9153252
SUNY at Albany	FY 91 $ 41,000
Albany, NY 12201	12 months

A revised calculus curriculum is being adapted, refined, and implemented. The faculty are attending workshops and computer-calculus classes.

Dissemination of Project CALC Methods and Materials

Lawrence C. Moore	Award No: USE 9153272
Duke University	FY 91 $ 162,165
Durham, NC 27706	FY 92 $ 97,294

Third-semester calculus materials are being completed for teaching calculus as a laboratory course. The work includes the expansion of the repertoire of classroom and laboratory projects, development of versions of alternate software and hardware environments, and completion of a high school version of the course. The methods and materials for all three semesters are being evaluated and widely disseminated by workshops for college-level and pre-college faculty, by continued publication of a newsletter, and by production of preliminary materials.

Calculus & Mathematica at Ohio State

William J. Davis	Award No: USE 9153246
Ohio State University	FY 91 $ 99,916
Columbus, OH 43210	FY 92 $ 91,277

The Calculus & Mathematica course is being extended to second year calculus. The focus is on developing of materials, testing them in the classroom, and revising them in light of the experience gained. Student outcomes are being assessed and the results reported to the community.

Complete Implementation of a Mathematica Laboratory for Calculus at a Public Metropolitan University

Richard E. Mercer	Award No: USE 9153300
Wright State University	FY 91 $ 91,629
Dayton, OH 45435	24 months

Materials are being adapted and new materials developed to implement a laboratory calculus course. The materials emphasize extensive use of Mathematica programming, especially graphics routines and conceptual questions that require written responses in paragraph form. The curricular changes emphasize a systematic treatment of the approximation of functions throughout the calculus sequence.

Implementation and Adaptation of St. Olaf First-Year Calculus in the Schools of the Chattanooga Consortium

Stephen W. Kuhn	Award No: USE 9153285
University of Tennessee	FY 91 $ 65,000
Chattanooga, TN 37403-2598	FY 92 $ 70,000

Faculty at the university, college, and high school levels are working together to improve their curriculum by adapting and implementing the model calculus program being developed. Graphical, numerical, and algebraic viewpoints are brought to bear on calculus ideas to improve students' conceptual understanding.

Gems of Exposition in Elementary Linear Algebra

Charles R. Johnson
College of William and Mary
Williamsburg, VA 23185

Award No: USE 9153284
FY 91 $ 92,000
24 months

Efforts are underway to collect and broadly disseminate gems of exposition in elementary linear algebra. These include especially insightful proofs, short and open-ended problems, longer expositional items, and machine-oriented, computational exercises, all of which are designed to communicate fundamental linear algebra ideas to beginning students. Items are being solicited from a wide range of individuals worldwide and are being published in a volume designed to be available at low cost.

Multi-HBCU Calculus Project

Walter Elias
Virginia State University
Petersburg, VA 23803

Award No: USE 9153264
FY 91 $ 50,000
FY 92 $ 100,000

The calculus curriculum is being revised. A problem solving approach that encourages experimentation and enhances the study of calculus by minority students is being implemented. The primary technical tool is the microcomputer running the computer algebra system Derive.

The Washington Center Calculus Dissemination Project

Robert S. Cole
Evergreen State College
Olympia, WA 98505

Award No: USE 9153274
FY 91 $ 80,062
FY 92 $ 145,348

Faculty from a consortium of diverse institutions are adapting, refining, and implementing approaches to teaching calculus. A select group of about twenty faculty are being trained in the new methods. This core of faculty trains faculty from twelve additional institutions, and all those involved adapt and implement one of the new approaches at their home institutions.

PROJECT ABSTRACTS: FY 1990 AWARDS

Software and Project Development for the Two-Year Calculus Sequence

David O. Lomen	Award No: USE 9053431
University of Arizona	FY 90 $ 80,000
Tucson, AZ 85721	FY 91 $ 90,000

Calculus students at many institutions are benefiting from integrated supplements: laboratory exercises, projects, problems, and software packages. The laboratory exercises are modeled after a typical chemistry or physics laboratory, projects involve the student discovering and conjecturing results, and problems are challenging and realistic. The software packages provide materials and facilities, and run on MS-DOS or Apple Macintosh machines.

Implementing Calculus Reform: Conferences, Classroom Testing, and Dissemination

Michael R. Colvin	Award No: USE 9053404
California Polytechnic State University	FY 90 $ 46,996
San Luis Obispo, CA 93407	12 months

A forum is being established for the dissemination and classroom testing of innovative ideas, pedagogy, and technological advances in teaching calculus. Classroom testing is taking place on campuses under the auspices of the California Calculus Consortium. Faculty are introduced to innovative approaches via a summer workshop, and these approaches are reinforced through follow-up activities during the academic year.

Computer Simulated Experiments in Differential Equations

David A. Horowitz	Award No: USE 9053390
Golden West College	FY 90 $ 36,000
Huntington Beach, CA 92647	12 months

Calculus students are improving their understanding of applied mathematics with the help of computer simulation programs that pictorially and graphically model real-life applications. The package includes growth and decay simulations and harmonic motion simulations.

Computer Projects and Software for the Introductory Linear Algebra Course

Gareth Williams	Award No: USE 9053365
Stetson University	FY 90 $ 24,964
Deland, FL 32720	12 months

The introductory linear algebra curriculum that is typically part of the two-year calculus sequence is being revitalized by the introduction of computer projects and related material. The projects are diverse in nature, ranging from those that explore mathematical concepts to those that involve mathematical models.

Calculus and Mathematica

J. Jerry Uhl	Award No: USE 9053372
University of Illinois	FY 90 $ 87,501
Urbana, IL 61801	FY 91 $ 90,004

Students are discovering the concepts and ideas of calculus by exploration and experimentation in a revitalized calculus course, Calculus & Mathematica, that combines the concept of calculus as a laboratory science with correct mathematical foundations. The classroom/laboratory is equipped with Macintosh computers and the text materials are presented via the Notebook feature of Mathematica.

Calculus, Concepts, and Computers

Edward L. Dubinsky	Award No: USE 9053432
Purdue University	FY 90 $ 220,000
West Lafayette, IN 47907	FY 91 $ 226,000
	FY 92 $ 200,000

Students are learning both the geometric aspects of calculus using computer graphics and the mathematical concepts via a mathematical programming language that allows them to make standard mathematical constructions using standard mathematical notation; drill and practice are being reduced by using a computer algebra system. Research into the process of learning the underlying ideas of calculus is also being conducted.

Engineering/Physical Science Second Year Calculus and Differential Equations: A Pilot Project

Leslie Hogben | Award No: USE 9053428
Iowa State University | FY 90 $ 48,241
Ames, IA 50011 | 12 months

Students in fourth semester calculus, differential equations, and linear algebra are benefiting from a revised curriculum that presents the underlying mathematics by introducing physical problems which require mathematics for their solution.

Calculus with Computing: A National Model Course

Keith D. Stroyan | Award No: USE 9053383
University of Iowa | FY 90 $ 64,000
Iowa City, IA 52242 | FY 91 $ 66,000

Students in the Accelerated Calculus Program are benefiting from a new curriculum that treats beginning calculus as a laboratory course with NeXT computers and Mathematica software as the equipment. Students, in classes of 125, work on open-ended projects with assistance from graduate teaching assistants, upperclass undergraduates, and faculty.

A Reformed Calculus Program Based on Mathematics and Project CALC

William H. Barker | Award No: USE 9053397
Bowdoin College | FY 90 $ 35,000
Brunswick, ME 04011 | FY 91 $ 44,000

Students are learning calculus in a discovery-based laboratory course using materials developed at Duke University and adapted for use in a liberal arts college setting. The course and laboratory materials are made available for Macintosh computers and exploit the Notebook feature of the computer algebra system, Mathematica.

Computer Algebra System Workshops, New Series

Donald B. Small | Award No: USE 9053427
Colby College | FY 90 $ 84,875
Waterville, ME 04901 | FY 91 $ 10,000

College and pre-college faculty are learning how to use computer algebra systems in the teaching of calculus. Strong emphasis is placed on using these systems in such a way that the calculus curriculum is improved by introducing numerical and graphical experimentation, and by focusing on problem-solving and understanding of concepts.

A Workshop on the Undergraduate Linear Algebra Curriculum

David Lay | Award No: USE 9053422
University of Maryland | FY 90 $ 43,922
College Park, MD 20742 | 12 months

Mathematical Scientists are assessing the current state of linear algebra instruction in the undergraduate curriculum, laying a foundation for its improvement, and identifying priorities for further and continuing study. This endeavor is being carried out by means of a survey of linear algebra curricula, a workshop, and a conference.

Video Applications Modules in Calculus

Frank R. Giordano | Award No: USE 9053407
Consortium for Mathematics & Its Applications, Inc. | FY 90 $ 101,851
Arlington, MA 02174 | 12 months

A calculus video applications library is being produced that will expose students to exciting applications of mathematics, and includes a printed teacher's guide. The modules can also be used in faculty development activities and contain print packages with special attention to showing how to introduce these ideas into the classroom.

A Modular Calculus

William W. Farr | Award No: USE 9053430
Worcester Polytechnic Institute | FY 90 $ 56,981
Worcester, MA 01609 | FY 91 $ 61,572

Students are benefiting from a new calculus curriculum that features early development of multivariable functions and derivatives, a less sequential approach to the calculus topics, and the development of team projects with computer laboratories and written laboratory reports.

Computers in Calculus, The Dearborn Project

David A. James | Award No: USE 9053385
University of Michigan | FY 90 $ 57,500
Dearborn, MI 48128 | FY 91 $ 59,000

Calculus students are benefitting from a new curriculum constructed from the best curriculum development efforts around the country. After classroom testing, the results are being evaluated and a package of computer laboratory materials and an instructor's manual is being desktop-published and disseminated.

First-Year Calculus From Graphical, Numerical, and Symbolic Points of View

Arnold M. Ostebee	Award No: USE 9053363
Saint Olaf College	FY 90 $ 49,977
Northfield, MN 55057	FY 91 $ 54,965

A new curriculum combining graphical, numerical, and algebraic viewpoints on the main ideas and objects of calculus and SUPPORTED by modern computing technology is helping students understand calculus ideas more deeply and apply them more effectively.

A Model Program Using Student Research Projects in Calculus and Differential Equations

David J. Pengelley	Award No: USE 9053387
New Mexico State University	FY 90 $ 120,000
Las Cruces, NM 88003	24 months

Calculus students are benefiting from a newly designed course in vector calculus and differential equations that equips them with the basic tools of modern mathematical modeling. As a result of analyzing a sequence of discovery projects, students see how real-world questions may engender theoretical tools and how these tools may then be extended to new applications. The independent experimentation, conjecture, and testing this fosters builds the confidence needed for independent work or group leadership. Several national workshops are being held on departmental implementation of a projects-based calculus curriculum, as well as a conference on using discovery projects to teach basic ideas in calculus and differential equations.

Computer Enhancement Options for Second Year Calculus

George R. Livesay	Award No: USE 9053426
Cornell University - Endowed	FY 90 $ 93,000
Ithaca, NY 14853	FY 91 $ 97,000

Specialized software packages are being developed for the differential equations and vector and multivariable calculus topics typically included in a second-year calculus course. The new software is modeled after the MacMath and Analyzer packages already completed and classroom tested.

Developing a Projects-Based Calculus Curriculum

Stephen R. Hilbert — Award No: USE 9053416
Ithaca College — FY 90 $ 86,175
Ithaca, NY 14850 — 24 months

Students are achieving increased understanding of concepts, seeing the unity of the important topics in calculus, obtaining a deeper geometric understanding, and learning problem-solving skills in a new calculus course that integrates large, open-ended problems into the curriculum.

A Laboratory Approach to Calculus

L. Carl Leinbach — Award No: USE 9053401
Gettysburg College — FY 90 $ 59,225
Gettysburg, PA 17325 — 8 months

College faculty are learning how computer algebra systems can be used to improve calculus curricula and are designing new curricula that integrates laboratories into the new courses. The new designs being implemented are critiqued and redesigned at a follow-up workshop.

Duke University's Project CALC Test Site

Alvin J. Kay — Award No: USE 9053364
Texas A&I University — FY 90 $ 17,664
Kingsville, TX 78363 — 12 months

Students are learning calculus in a laboratory setting and are discovering for themselves the concepts and problem solving power of calculus. The overall framework of the laboratory and the course materials being used were developed at Duke University and are being tested in this setting.

PROJECT ABSTRACTS: FY 1989 AWARDS

Curriculum Development Project: Calculus

David O. Lomen — Award No: USE 8953930
University of Arizona — FY 89 $ 104,806
Tucson, AZ 85721 — 12 months

Materials are being developed that complement the calculus courses at major universities throughout the nation. Integrated supplements are being developed that feature laboratories, projects, problems, and software packages. Laboratories are modeled after a typical physics or chemistry laboratory where the student performs guided experiments independent of the present class material. Projects involve the student discovering and conjecturing results related to calculus. Problems are challenging, realistic questions that might require modern technology to solve. All problems are technology dependent, but independent of a specific brand of computer. The software packages will bridge this gap by supplying the appropriate materials for MS-DOS and Macintosh machines.

Calculus and Computers: Toward a Curriculum for the 1990s

Marcia C. Linn — Award No: USE 8953974
University of California — FY 89 $ 42,898
Berkeley, CA 94720 — 12 months

Faculty from a broad spectrum of institutions, including two-year colleges, are learning ways to use Mathematics and exchanging ideas on how to use this powerful tool in the teaching of calculus. The invited speakers at the conference and the PIs are using Mathematica and other integrated symbol manipulation and graphics systems in their calculus courses and are seeing exciting possibilities for their use. The conference participants are learning about these systems and are making suggestions about ways to use these tools.

Rapid Dissemination of New Calculus Projects

Thomas W. Tucker — Award No: USE 8953912
Mathematical Association of America — FY 89 $ 41,540
Washington, DC 20001-0000 — 12 months

Detailed descriptions (syllabi, assignments, laboratories, exams, sample text material, preliminary assessment) of eight to ten new calculus projects are being prepared for publication. Project summaries of approximately 50 additional projects are included.

Calculus Curriculum Development

J. Jerry Uhl	Award No: USE 8953906
University of Illinois	FY 89 $ 25,000
Urbana, IL 61801	12 months

A non-traditional, entirely new course is being developed under this pilot project through live Mathematica notebooks. Emphasis is placed upon individual student use of the Mathematica program for instruction, computation, and symbolic manipulation within the Mathematica notebooks. The goal is to motivate the students to better understand the foundations and enable them to execute calculations far beyond those expected of students in the traditional course.

Calculus Redux

Judith H. Morrel	Award No: USE 8953948
Butler University	FY 89 $ 27,000
Indianapolis, IN 46208	12 months

Students are finding more excitement and making better progress in calculus because of a revised curriculum that emphasizes problem solving, building intuition, and improving written mathematical expression. A data base consisting of non-routine, open-ended, multi-step problems and discussion modules emphasizing concepts, experimentation, and widely varying applications is being created.

A Revitalization of an Engineering/Physical Science Calculus

Elgin H. Johnston	Award No: USE 8953949
Iowa State University	FY 89 $ 63,600
Ames, IA 50011	FY 90 $ 72,250
	FY 91 $ 58,565
	FY 92 $ 15,000

A four-year program is under way to revitalize the calculus course taken by science, engineering, and mathematics students. The revised curriculum stresses the modeling and problem-solving aspects of calculus, and teaches students to use commercially available symbolic and numerical software to handle the technical aspects of the subject. The planning, testing, and implementation of the new curriculum is being done under the guidance of a liaison committee made up of faculty from the physical sciences, engineering, and mathematics departments.

Calculus with Computing: A National Model Course

Keith D. Stroyan	Award No: USE 8953937
University of Iowa	FY 89 $ 65,000
Iowa City, IA 52242	12 months

The curriculum is being developed to present calculus as the language of science. Beginning calculus is being treated as a laboratory course with modern computers and scientific software as the laboratory equipment. The development is built on a long history of successful use of computers in a calculus laboratory and will make use of new software so that students have a serious start on their education in scientific computation.

Core Calculus Consortium: A Nationwide Project

Andrew M. Gleason	Award No: USE 8953923
Harvard University	FY 89 $ 346,245
Cambridge, MA 02138	FY 90 $ 570,283
	FY 91 $ 335,223
	FY 92 $ 418,372
	FY 93 $ 337,500

A National consortium of institutions is developing an innovative core calculus curriculum that is practical and attractive to a multitude of institutions. The refocus of calculus uses the "Rule of Three" whereby topics are explored graphically, numerically, and analytically. The consortium is led by Harvard University and consists of the University of Arizona, Colgate University, Haverford-Bryn Mawr Colleges, the University of Southern Mississippi, Stanford University, Suffolk Community College, and Chelmsford High School.

Calculus Reform in Liberal Arts College

A. Wayne Roberts	Award No: USE 8953947
Macalester College	FY 89 $ 199,203
Saint Paul, MN 55105	FY 90 $ 215,168
	FY 91 $ 148,500

A calculus curriculum is being developed that stresses understanding rather than techniques, contains realistic applications, and promotes the ability to write coherent arguments. This development is being carried out with the participation of twenty-six liberal arts colleges in the Midwest and takes the form of five Resource Collections containing fundamental materials that can be used in part or in total for curriculum development in calculus at any institution. These collections are to be published as five separate volumes.

The St. Olaf Conference, October 20-22, 1989

Paul D. Humke | Award No: USE 8955091
Saint Olaf College | FY 89 $ 1,500
Northfield, MN 55057 | 6 months

Paul D. Humke	Award No: USE 8955091
Saint Olaf College	FY 89 $ 1,500
Northfield, MN 55057	6 months

Mathematicians experienced in using computer algebra systems in teaching calculus are meeting to discuss their past experience and their plans for future use. The focus is on how these systems have changed, can change, and will change the teaching of calculus.

Utilization of Technology in Non-traditional Calculus

Wanda Dixon	Award No: USE 8953931
Meridian Community College	FY 89 $ 25,000
Meridian, MS 39301	18 months

The calculus curriculum is being revised to place more emphasis on learning the concepts, solving realistic problems, and improving estimation of skills. Materials are being developed to utilize the HP-285 hand-held calculator.

Calculus: Restructuring and Integration with Computing

Richard H. Crowell	Award No: USE 8953908
Dartmouth College	FY 89 $ 289,171
Hanover, NH 03755	

The calculus curriculum is being restructured by integrating into the syllabus student use of a personal computer as a working tool. A substantial body of new courseware is being created that enables the students to use a personal computer as a regular part of their homework to explore, analyze, or verify the central concepts of the calculus, is being created. Students are expected to write some of their own software and/or to modify existing software as an integral part of the course. The course materials are being substantially restructured in order to incorporate the advantages which the presence of the computer affords. The ultimate goal is to produce a new computer-based calculus text.

C4L Calculus Computers, Calculators and Collaborative Learning

Patricia R. Wilkinson	Award No: USE 8953959
CUNY Borough of Manhattan Community College	FY 89 $ 50,000
New York, NY 10007	24 months

The collaborative learning project is providing students, especially those from minority groups, a better chance to achieve success in calculus. The students are working in informal study groups with the assistance of specially trained tutors.

Calculus in the Liberal Arts Curriculum/Multidisciplinary Resources for College Calculus

Ronald W. Jorgensen	Award No: USE 8953926
Nazareth College of Rochester	FY 89 $ 78,232
Rochester, NY 14610	24 months

A calculus curriculum that uses the computer algebra system MAPLE in conjunction with writing assignments that are designed to promote student learning is being developed. The courses are organized in diagnostic learning units and require students to keep a journal which is regularly evaluated by the instructor. This system of ongoing feedback between student and teacher enhances self-evaluation on the part of the student.

The Computer Revolution in Calculus: Innovative Approaches to Concepts and Applications

William E. Boyce	Award No: USE 8953904
Rensselaer Polytechnic Institute	FY 89 $ 55,000
Troy, NY 12180-3590	12 months

A new calculus course that exploits the power of a computer as an integral part of teaching and learning is being designed. Advantage is being taken of a computer's capacity to perform numerical computation, produce sophisticated graphics, and carry out extensive symbolic manipulations. Students are provided with powerful and versatile problem-solving tools and simultaneously gain a deeper understanding of the underlying mathematical concepts.

Project CALC: Calculus as a Laboratory Course

Lawrence C. Moore	Award No: USE 8953961
Duke University	FY 89 $ 198,522
Durham, NC 27706	FY 90 $ 217,773
	FY 91 $ 134,570
	FY 92 $ 39,999

Students are benefiting from a completely restructured calculus curriculum. The new curriculum features an integrated computer laboratory for exploration and development of intuition, and emphasizes writing to promote student comprehension and expression.

Calculators in the Calculus Curriculum

Thomas Dick
Oregon State University
Corvallis, OR 97331-5503

Award No: USE 8953938
FY 89 $ 84,219
FY 90 $ 75,371
FY 91 $ 87,918
FY 92 $ 15,000

Calculus students are benefiting from the joint effort involving universities, two- and four-year colleges, high schools, and high technology industry to develop and implement a new calculus curriculum which makes integral use of symbolic/graphical calculators. Text materials appropriate for the equivalent of three semesters of calculus are being produced and classroom-tested in a variety of instructional settings. Workshops provide continuing instructional support for teachers using the curriculum materials and symbolic/graphical calculator.

The Calculus Companion: A Computational Environment for Exploring Mathematics

Edmund A. Lamagna
University of Rhode Island
Kingston, RI 02881

Award No: USE 8953939
FY 89 $ 161,535
36 months

The calculus curriculum is being revised to provide students with more complex, real world problems, to help them develop the skills involved in performing multi-step reasoning, and to help them learn to express mathematical ideas precisely and coherently. A unique computational environment is being developed in which students use the computer as both a tutoring device and a computational aid. The system, called the Calculus Companion, consists of a user-friendly interface to the computer algebra system MAPLE and numerical computation and graphical display routines.

PROJECT ABSTRACTS: FY 1988 AWARDS

An Integrated Program in Calculus and Physics

F. Richard Yeatts	Award No: USE 8813784
Colorado School of Mines	FY 88 $ 74,517
Golden, CO 80401	FY 89 $ 47,451
	FY 90 $ 83,058

An integrated calculus and physics course is being developed and tested. A unique feature is the well-planned laboratory/workshop session where much of the integration of the subject matter occurs. The sessions provide students with the opportunity to explore and discover the relationships between a physical situation, its graphical or geometric representation, and the corresponding analytical representation. The workshop exercises consist of physics experiments, numerical simulations, symbolic manipulations, computer programming, and formal reasoning exercises. Study guides, problem sets, and modular materials are being developed. The students' progress is being evaluated internally as well as externally by a National Advisory Committee.

The Design of a Computer Algebra System to Effect a More Relevant Mathematics Curriculum

J. Douglas Child	Award No: USE 8814048
Rollins College	FY 88 $ 73,436
Winter Park, FL 32789	FY 89 $ 43,126
	FY 90 $ 44,076

The focus of the three-year project is the construction of a computer environment consisting of a computer algebra system, MAPLE, a specially designed interface to MAPLE, a hypertext system, and other software that is more suitable for teaching and learning calculus for the average student. The computer algebra system demonstrates the reasoning processes of experts. The intent is that students will learn how to think about solving calculus as well as how to solve problems with the help of a computer algebra system. The computer environment is suitable for pre-calculus, science, and engineering curriculum designs. A computer algebra system, both to do and to teach calculus with MAPLE, is being developed along with curriculum and interfaces for computer algebra systems. The calculus topics are being reordered introducing differentiation and integration early in the course via applied problems. Emphasis is being placed on logic, precise use of language, numerical methods, approximations, and mathematical modeling. Experimental use of materials is taking place at colleges and local high schools which have classes of approximately thirty-five students. National dissemination is in the form of text to be published by Wadsworth/Brooks-Cole Publishers.

Calculus Workshops and Conferences

Shair Ahmad — Award No: USE 8813860
University of Miami — FY 88 $ 45,000
Coral Gables, FL 33124 — 12 months

The project is developing a monthly series of two-day conferences and workshops on calculus to be attended by university and community college faculty members, high school calculus instructors, and industrial representatives. The seminars concentrate on the role of computers and calculators, textbooks, relevance to other disciplines, conceptual understanding, and the development of exercises that stress current technology. Discussions are led by small groups of well-prepared individuals familiar with existing literature on the subjects. Participants are encouraged to carry on similar discussions in their own institutions.

Calculus Planning Project

Nagambal D. Shah — Award No: USE 8813792
Spelman College — FY 88 $ 50,000
Atlanta, GA 30314 — 12 months

The project is planning a series of seminars focusing on the special needs that women have in the study of calculus and mathematics, and culminating in a faculty retreat and the writing of a report on the faculty members shared experiences. The project is being held at a black institution for females with strong academic traditions and includes formal participation by the chairman of the mathematics department at Agnes Scott College, a female institution with equally strong academic traditions. The program starts with three seminars lead by consultants with special expertise in the area of female studies in mathematics. The presentations and consultations should sensitize the faculty participants to the special elements of females studying mathematics. Three additional consultants will assist with three later seminars that concentrate on the role of computers in the study of calculus. A pilot section of calculus uses and investigates computer software specially designed to assist in the study of calculus. Three undergraduate students help with the evaluation of the materials. With the help of the specialized consultants, the faculty becomes sensitive to the issues involved in the instruction of female student.

Calculus Curriculum Development

Gerald J. Janusz — Award No: USE 8813873
University of Illinois — FY 88 $ 40,785
Urbana, IL 61801 — 12 months

Mathematicians are investigating methods by which the teaching of calculus can be made more effective in conveying to students an understanding of calculus as a powerful problem solving tool. Course material planning focuses on the development of the problem sets that lead students through the central ideas and methods of calculus and enhance their ability to read and write mathematics. The project consults with user departments in science, engineering, and other areas; develops and tests course material for Calculus I based on an approach of Artin; focuses on computational and problem solving; and develop student capacity to read and write mathematics correctly and coherently. A weekly Calculus Seminar trains teaching assistants and discusses content among faculty within and outside the mathematics department. A Calculus Workshop for faculty and high school teachers is being held.

Calculus, Concepts and Computers

Edward L. Dubinsky	Award No: USE 8813996
Purdue University	FY 88 $ 30,000
West Lafayette, IN 47907	12 months

Three mathematicians are teaching three small (25-30 students) prototype calculus courses based on computer, computer languages, and algebra systems. The geometric and conceptual aspects of calculus, solution of applied problems, and reduction of routine drill by using symbolic manipulation is emphasized. These courses include both mainstream and non-mainstream calculus. The extent of the use of computer labs and the use of the ISTEL and Maple software packages varies. A consulting board of 25 experts from the various academic disciplines will suggest applications from science and mathematics from the latter third of the 20th century. A unique component of the project is research on how students come to understand the underlying ideas in calculus. Theoretical analysis, observations, and experiments on the teaching and learning of calculus are being formulated.

Planning for a Revitalization of an Engineering/Physical Science Calculus

Elgin H. Johnston	Award No: USE 8813895
Iowa State University	FY 88 $ 49,954
Ames, IA 50011	12 months

Mathematicians are revising the engineering calculus sequence by incorporating modeling and symbolic/graphical/numerical software into the curriculum. The planning is done by a committee of faculty from engineering, physical, and mathematical sciences. A calculus network of high school, community college, and college/university is being established. Over 90% of the calculus students are from the client disciplines. The project initiates change in a deliberate and timely manner with concurrence by the client departments. One fourth of the first-semester calculus courses are taught under the revised curriculum requiring a small amount of programming, and stressing algorithms and sharply focused real applications. The second and third semesters of calculus are being revised within the same mathematical framework.

Dynamic Calculus

Robert L. Devaney	Award No: USE 8813865
Boston University	FY 88 $ 40,306
Boston, MA 02215	12 months

An expert fluid dynamicist is developing instructional modules, which incorporate ideas from modern dynamical systems theory into the standard introductory calculus course. The purpose of the project is to augment the calculus with topics of current research interest. Materials can be introduced early in a calculus sequence so that students receive early exposure to topics of contemporary research interest in mathematics, computer experimentation in mathematics, and exciting mathematical visual images. Several modules which show how certain topics in dynamics may be integrated into calculus, and the role of dynamical calculus in science are being developed.

Calculus in Context

James Callahan	Award No: USE 8814004
Five Colleges, Inc.	FY 88 $ 141,707
Amherst, MA 01002	FY 89 $ 190,845
	FY 90 $ 174,183
	FY 91 $ 129,392
	FY 92 $ 74,128

Mathematicians are restructuring the standard three-semester calculus sequence. A new curriculum is being developed in which the four mathematical themes of optimization, estimation and approximation, differential equations, and functions of several variables are stressed from the beginning. These major mathematical concepts grow out of exploring significant problems from social, life, and physical sciences. Dynamical systems, discrete time models, Fourier series, and partial differential equations are some of the concepts which are explored. The computer is being integrated into the curriculum as a basic conceptual device for structuring the way students think about problems and what it means to solve them. Dissemination is in the form of team-taught courses, weekend retreats, summer workshops for area faculty and high school teachers, and publication of the curriculum. These instructional materials are used at universities, liberal arts colleges, and high schools.

The Language of Change: A Project to Rejuvenate Calculus Instruction

Andrew M. Gleason | Award No: USE 8813997
Harvard University | FY 88 $ 20,362
Cambridge, MA 02138 | 12 months

A group of mathematicians is designing calculus syllabi outlines. They are investigating the use of computers/calculators in opening up new topics and new ways of teaching. They are completely rethinking the goals and content of calculus courses to establish closer collaboration with representative of client disciplines; to plan the creation of tests; and to plan the development of materials to be used in workshops on pedagogy.

Calculus Reform in Liberal Arts College

A. Wayne Roberts | Award No: USE 8813914
Macalester College | FY 88 $ 62,650
Saint Paul, MN 55105 | 12 months

Mathematicians are developing a one-year mainstream calculus course. The curriculum stresses basic concepts; numeric and graphic experiments to better understand the power and limitations of technology; the role that calculus plays in changing people's world view; the art of writing a deductive argument; and applied mathematics as a creative modeling process. Outlines of teaching resources to create a lean and lively one-year calculus course include sequences of laboratory style problems; textbook type problems for computers/calculators; application modules; open ended problems; and historical vignettes.

Calculus: Restructuring and Integration with Computing

Richard H. Crowell | Award No: USE 8814009
Dartmouth College | FY 88 $ 50,464
Hanover, NH 03755 | 12 months

Mathematicians are integrating computers into, and planning the restructuring of, the calculus curriculum. The approach emphasizes elementary functions and the use of the computer for graphical displays and computation of tables of function values. Student written programs are being used to investigate these functions. Differentiation and integration are taught by means of the difference calculus, making heavy use of the computer. These concepts are used to solve "real-world" problems. Students are expected to gain a deeper understanding of calculus concepts from the combination of theory, applications, and computer investigations. During the four-course calculus sequence, students are developing the capabilities of doing their own numerical and graphical investigations independently. Text and computer materials, demonstration programs, and problems are being developed. The new curriculum is being tested and evaluated.

From Euclid to von Neumann, an Activity-Based Learning Experience in Calculus: Project ENABLE

Joan Ferrini-Mundy	Award No: USE 8814057
University of New Hampshire	FY 88 $ 40,487
Durham, NH 03824	12 months

Mathematicians, mathematics educators, engineers, scientists, high school teachers, and Technical Education Research Center are developing and refining mathematical, educational, and technological perspectives for a three-semester calculus curriculum. The project is first conducting a baseline assessment of first-semester calculus students to determine their algebra and trigonometry skills, as well as their understanding of essential precalculus concepts. Implementation of the reorganized and streamline curriculum requires a clear perception of the students' knowledge base and misconceptions, as well as the students' active participation in their own learning. The curriculum starts with the concept of approximation, whose idealization will lead to derivatives, integrals, and continuity. Biweekly seminars to develop prototype materials, outline modules, and core units are being held during the academic year. Some components are being tested in high schools.

Student Research Projects in the Calculus Curriculum

Marcus S. Cohen	Award No: USE 8813904
New Mexico State University	FY 88 $ 83,572
Las Cruces, NM 88003	FY 89 $ 98,993
	FY 90 $ 59,652

Mathematicians continue to develop and implement a plan using student research projects in a broad range of calculus courses. Three individual two-week projects are being used instead of hour exams in thirty-five calculus sections. Almost one-half of the students are minorities. A collection of four hundred problems, many annotated with information on their success in the classroom is being compiled. The projects require that students think broadly and deeply, identifying background material, and synthesizing an approach. Scientists, engineers, and economists help design projects which demonstrate the mathematical underpinnings of solutions to applied problems. Faculty workshops, training of teaching graduate assistants, Advisory Committee meetings, and an extensive evaluation which includes evaluating long-term intellectual growth of students are all taking place as part of the project.

Planning a Problems-Based Calculus Curriculum

Stephen R. Hilbert	Award No: USE 8814177
Ithaca College	FY 88 $ 50,193
Ithaca, NY 14850	18 months

Mathematicians are developing a problem-based mainstream calculus curriculum. The complex problems will require a minimum of several weeks to solve. The structure of the problems varies from "case study" to "open-ended". Groups of students working together will solve problems which develop essential parts of the calculus, and use calculator/computers where relevant. In-depth interviews with twenty-five faculty members from accounting, biology, chemistry, economics, finance, management, politics, psychology, and physics help identify realistic problems. Two experimental course sections of Calculus I are being taught, and a one-day conference on the "Future of Calculus" is being held.

Calculus and the Computer: Innovative Teaching and Learning

William E. Boyce — Award No: USE 8814011
Rensselaer Polytechnic Institute — FY 88 $ 50,000
Troy, NY 12180-3590 — 12 months

Applied mathematicians are developing a calculus course sequence in which computer technology is used to equip students with powerful and versatile problem-solving tools in order to gain deeper understanding of the underlying mathematical concepts. Content includes numerical computation, sophisticated graphics, symbolic computation, relations between mathematics and the natural world, and mathematical modeling. A team of mathematicians, a physicist, an electrical engineer, and students are developing instructional materials to support the use of the computer in calculus. These materials are used in two or three pilot sections of the calculus sequence.

Development of Calculus

Lawrence C. Moore — Award No: USE 8814083
Duke University — FY 88 $ 20,000
Durham, NC 27706 — 12 months

A detailed syllabus for a new calculus curriculum is being developed in a cooperative venture with an area high school. The schools are experimenting with the use of computer algebra systems and preparing sample modules. A small prototype calculus laboratory is being run for the development and testing of interactive experiments and writing as a learning tool in mathematics. Central themes include appropriate use of mathematical and physical tools, identification of a concept and its inverse, use of transformations, and relationships between calculus and real world problems.

Toward a Conceptual and Captivating Calculus

Thomas A. Farmer
Miami University Oxford Campus
Oxford, OH 45056

Award No: USE 8813786
FY 88 $ 48,595
12 months

The project is developing a lean and lively calculus syllabus for college students who have had calculus in high school. After consultation with scientists from client disciplines on the current uses of calculus, materials incorporating computers are being developed to run a preliminary experiment. A large-scale, controlled experiment with teaching and computing materials is being prepared.

Plan for Calculators in the Calculus Curriculum

Thomas Dick
Oregon State University
Corvallis, OR 97331-5503

Award No: USE 8813785
FY 88 $ 27,401
12 months

A calculus curriculum which makes essential use of the HP285 symbolic/graphical calculator is being developed and implemented. The objectives are: to identify calculus topics pedagogically suited for use on symbolic/graphical calculators; to identify roles of symbolic/graphical calculators in calculus; and the production of curriculum/calculator materials to be tested during the academic year. A calculus book based on the symbolic/graphical calculator provides both technical advice regarding the calculator and adaptation of the calculus text materials. A series of workshops on utilizing the symbolic/graphical calculator in mathematics classes is being presented.

Integrated Calculus Development

Alain Schremmer
Community College of Philadelphia
Philadelphia, PA 19107

Award No: USE 8814000
FY 88 $ 40,124
12 months

The project is developing a Lagrangian calculus program for the students who are predominantly women, minorities, and returning adults. Lagrangian calculus develops concepts via polynomial approximations rather than limits. It reduces questions about "any" function to the same question about a power function, which appears in the approximating polynomial. The two-semester course is equivalent to pre-calculus and one semester of calculus. The first semester consists of linear approximations, quadratic, and power functions. The second semester consists of the differential study of polynomials, Laurent polynomials, and rational and elementary transcendental functions by Lagrange's approach.

Revitalization of Calculus

Mary McCammon
Pennsylvania State University
University Park, PA 16801

Award No: USE 8813779
FY 88 $ 42,399
12 months

Mathematics faculty members are developing a lean and lively syllabus for a freshman science and engineering calculus sequence. In consultation with other mathematicians, scientists, and engineers, a core of essential material is being determined. Existing software, computer technology, and placement tests are evaluated and modified, as needed. A test which contains related software and supplements for instructors and which covers the central core of materials is being produced. Several aspects of the experimental syllabus are being taught by the instructors. Each participant experiments with only a small part of the curriculum. In this way, several content areas and approaches can be tested, while insuring that students are exposed to nearly all of the traditional calculus.

Proposal for a Newsletter on Collegiate Mathematics Education

James H. Voytuk
American Mathematical Society
Providence, RI 02901

Award No: USE 8814683
FY 88 $ 104,413
FY 89 $ 66,675
FY 90 $ 9,358
FY 91 $ 9,358

A collegiate mathematics education newsletter is being established. Its purpose is to stimulate greater communication between research mathematicians and collegiate mathematics educators. The newsletter provides a balance of short, timely items directing readers to sources of further information, and longer, more substantive articles presenting discussion of important issues in collegiate mathematics education. The newsletter includes the following: articles on mathematics curriculum; innovative teaching methods; funding for collegiate mathematics education; outside classroom activities; profiles of successful mathematics programs; information on conferences, workshops, courses, and use of technology; review of international activities; review of information in other publications; and a column for queries.

The Calculus Companion: A Computerized Tutor and Computational Aid

Edmund A. Lamagna
University of Rhode Island
Kingston, RI 02881

Award No: USE 8814017
FY 88 $ 51,350
12 months

The project is creating a computational environment in which calculus students use the computer as both a tutoring device and a computational aid. The system consists of two components: (1) a powerful user interface to a symbolic mathematics package and graphical display routines; and (2) tutorial modules. A study on how the computer can be best integrated into the calculus curriculum, and a prototypical course module on the topic of integration are being completed. Students are introduced to important techniques using symbolic computation facilities. The graphical and numerical capabilities demonstrate several numerical integration techniques. Real world examples from several client disciplines are used to motivate topics.

Restructuring One Variable Calculus within a Modeling and Computer Oriented Environment

Daniel C. Sloughter
Furman University
Greenville, SC 29613

Award No: USE 8813781
FY 88 $ 22,476
12 months

Mathematicians are developing and testing an experimental one variable calculus course which builds and analyzes realistic models of dynamic processes, including "chaos". The course restructuring starts with sequences of real numbers and difference equations, and ends with differential equations. Global and qualitative behavior is stressed by use of the computer. There is modeling with symbol manipulation, discrete mathematics, and numerical mathematical packages.

Development of Computer-Based Curriculum Materials for Calculus: A Planning Project

Michael E. Moody
Washington State University
Pullman, WA 99164-3140

Award No: USE 8814131
FY 88 $ 29,716
12 months

Mathematicians are developing, coordinating, and writing multi-disciplined computer-based curriculum materials for calculus to be implemented at two high schools, a community college, a private college, and a public university. Generic curriculum materials for engineering calculus, calculus for life sciences, and business calculus are being developed by faculty from engineering, biology, chemistry, business, and sociology. The materials include laboratory exercises that use computing devices such as HP-28 and microcomputers using symbolic manipulation programs. These realistic problems use numerical methods that illustrate the power, difficulties, and logic of computation and graphical solution to problems. Electronic "slide shows" with both animated and static computer graphics of classroom demonstrations and lectures are also being developed.

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Duke University's Project CALC Test Site

Virginia

College of William and Mary — Charles R. Johnson
USE 9153284 — 6
Williamsburg, VA 23185
Gems of Exposition in Elementary Linear Algebra

Virginia State University — Walter Elias USE
9153264 — 6
Petersburg, VA 23803
Multi-HBCU Calculus Project

Washington

Evergreen State College — Robert S. Cole USE
9153274 — 6
Olympia, WA 98505
The Washington Center Calculus Dissemination Project

Washington State University — Michael E. Moody
USE 8814131 — 28
Pullman, WA 99164-3140
Development of Computer-Based Curriculum Materials for Calculus: A Planning Project