DOCUMENT RESUME

ED 368 413 JC 940 218

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TITLE	Calculus Reform: Experiences of a Two-Year College Collaborating with Universities.
PUB DATE	Nov 93
NOTE	15p.; Paper presented at the Annual Meeting of the American Mathematical Association of Two Year Colleges (Boston, MA, November 18-21, 1993).
PUB TYPE	Reports - Descriptive (141) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Calculus; Community Colleges; Computer Assisted Instruction; *Consortia; Differential Equations; *Educational Change; Educational Technology; *Institutional Cooperation; *Mathematics Instruction; Mathematics Materials; Two Year Colleges
IDENTIFIERS	*Chattanooga State Technical Community College TN

ABSTRACT

As part of an effort to reform calculus instruction practices, Chattanooga State Technical Community College (CSTCC), in Tennessee, participates in two consortia. One consortium, the Chattanooga Calculus Consortium (CCC), is headed by the University of Tennessee at Chattanooga and involves one other four-year institution and three Chattanooga-area high schools. The CCC was funded by the National Science Foundation (NSF) in 1991 to adapt, implement, and evaluate calculus reform materials being developed at St. Olaf College; inform secondary schools about and involve them in calculus reform movements; prepare computer laboratory manuals; and prepare additional problem sets. The second consortium, the Western Appalachia Calculus Consortium (WACCO), is directed by the University of Kentucky and involves eight other higher-education institutions in three states. Funded by the NSF in 1992, WACCO was designed to share the identification, acquisition, and evaluation of reform approaches and materials through twice annual progress meetings; an Internet-accessible archive of materials; a journal; and workshops with high school educators. Additionally, CSTCC has been working to revise elementary differential equations to move students away from rote memorization to a meaningful understanding of differential equations. Participation in the consortia has benefited CSTCC in the following ways: theoretical and technological assistance has been provided with calculus reform and the college has been allowed input into the reform. The college has shared reform and technology with area high school teachers. (MAB)

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Chattanooga State Technical Community College is a member of two consortia dealing with calculus reform. One consortium, the Chattanooga Calculus Consortium (CCC) is headed by the University of Tennessee at Chattanooga and involves one other four-year institution (Southern College) and three Chattanooga-area high schools. The other consortium, the Western Appalachia Calculus Consortium (WACCO), is directed by the University of Kentucky and involves eight other higher-education institutions in three states. Chattanooga State is the only two-year institution in either consortium.

In both consortia, technology is used in the classroom, in laboratories, and to communicate among consortia members. In this paper, we will discuss the technological activities of both consortia as well as the experiences of being the only two-year college working with several universities. The various members of each consortium have developed exercises and laboratory projects that require students to use graphing calculators and various software packages. We have conducted workshops for high school teachers sharing ideas on how to implement technology in their mathematics classes.

1 Chattanooga State Technical Community College

Chattanooga State Technical Community College has a student body of approximately 10,000 of varying ages, economic status, races, abilities, and levels of preparation. The College serves five rural counties and one urban county in Tennessee, four rural counties in Georgia, and one rural county in northwestern Alabama, with a combined population of 621,000.

Students enrolled in the scientific-track of mathematics courses (precalculus and above) are required to

[1]A Paper Presented at the Annual Meeting of the American Mathematical Association of Two-Year Colleges, Boston, Massachusetts, November 18–21, 1993
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have a graphing calculator. No specific calculator is required, but most students opt for one from the *TI–8x* family. The department has three overhead versions of the *TI–81* calculator and the *TI–81* emulator is loaded on a mobile computer. All instructors use graphing calculators in their courses.

The use of computers is another story. Only three (of 12) faculty use computers in the non-statistics courses. (All statistics courses use computers, as described in another presentation at this conference by Herb Hooper and Bill Weigle.) While the College has several computer laboratories, only one is designated as a mathematics-science laboratory. This laboratory has 18 IBM-type, 386 computers. Only six can regularly be used by mathematics students. The other 12 computers have laser disks attached, and are used primarily for biology and chemistry. In addition there are a couple of other open computer laboratories available on campus that have PC's equipped which the same mathematics software found in the mathematics-science laboratory: Microcalculus, and Derive are all available on these PC's. We have a site license for Maple, but it requires Windows 3.1, and our computers have Windows 3.0. The program that we are currently using the most is Derive. Our reasoning behind this choice is that it is more versatile than Microcalculus and less difficult to learn than Maple. However, we plan to begin using Maple in Calculus I this Spring (1994) and in Calculus II in the summer.

2 Calculus Reform

For the last several years, the National Science Foundation has funded several projects in calculus reform. Some of the larger, and more prominent, of these are the following:

- The Harvard University Project (Deborah Hughes-Hallett and Andrew W. Gleason)
- The Duke University Project (David Smith)
- St. Olaf College (Arnold Ostebee and Paul Zorn)
- Mathematica (University of Illinois) (Jerry Uhl)
- Calculus: The language of change (Iowa) (K. D. Stroyan)
- Oregon State University (Thomas P. Dick and Charles M. Patton)

2.1 Why reform calculus

There were several major reasons why calculus reform started. Many people were concerned that a very large number of students that started calculus courses did not finish (of finished with a failing grade). It was perceived that calculus was acting (and being used) as a filter to keep students from pursuing their fields of interest. In particular, there seemed to be the following four reasons that people were calling for calculus reform:

- **Changing needs of society** Calculus is to prepare students for their roles in society, their jobs, etc. Many more areas were encouraging students to take calculus.
- **Dissatisfaction with the *status quo*** The calculus syllabus was becoming more crowded with topics. Every time someone had an ideas for a topics that should be included in a calculus course, it was added to the syllabus—but nothing was being removed.
- **New understandings about learning** Calculus does not demand deductive skills (at least at the first- and second-year levels). We were failing to identify students who would be good in mathematics and engineering. Furthermore, people seldom work alone, so why are we asking them to learn alone?
- **Technology** Our society is becoming more and more technological. We should help students see how to integrate technology into their learning and use of calculus.

2.2 What is calculus reform

While the different aspects of the projects may vary, most of them revolve around the same major theses.

- **Changes in emphasis** For example, less on techniques of integration. Emphasize concepts rather than techniques. Expose calculus I students to differential equations to better describe the "real world."
- **Interactive classroom** The instructor is not a lecturer as much as a guide. More group work. Collaborative learning.
- **New pedagogical strategies** Multiple ways of representing a function, *i.e.* the "rule of three": numerically, geometrically, and symbolically.

- **Using technology** Calculators and computers are a tool for learning concepts as well as working problems.

3 Chattanooga Calculus Consortium (CCC)

The Chattanooga Calculus Consortium (CCC) was funded by the National Science Foundation (NSF), Division of Undergraduate Education, in 1991 (1) to adapt, implement, and evaluate reform calculus materials being developed at St. Olaf College by Arnold Ostebee and Paul Zorn and (2) to inform area secondary schools of reform movements in calculus, (3) to involve area secondary school teachers in calculus reform, (4) to prepare computer laboratory materials, and (5) to prepare additional problem sets. The CCC is headed by the University of Tennessee at Chattanooga (UTC). During the first year, CCC included two four-year higher education institutions from the Chattanooga area (UTC and Southern College) and one two-year institution (CSTCC).

3.1 CCC History

One class in Calculus I was taught at each of these three institutions in Spring 1992. The three faculty members teaching these sections met each week to compare notes, to discuss areas of concern, inform each other of errors in the text, and to exchange answers to exercise sets. The text had no answers and we took turns preparing answers for various sections. These were duplicated and shared with students. Communications with Ostebee and Zorn were maintained by the UTC member via e-mail since, at that time, neither of the other two schools had direct access to e-mail. We (Southern and CSTCC) were given accounts on the UTC computer. This was of no use to CSTCC since we did not have a modem and, as a result, were not able to access the UTC computer from our institution. This continued to be the case until late September 1993, about two months ago.

During the 1992–93 academic year the CCC expanded to include three area high schools, one private (Girls Preparatory School) and two public (Ooltewah High School and Hixson High School). At both CSTCC and UTC, beginning Fall 1992, two sections were taught using the Ostebee-Zorn (OZ) text. During the Fall 1992 Semester, both sections were in Calculus I; and starting with the Spring 1993 Semester, there has been one section of Calculus I and one section of Calculus II. The OZ text serves as the primary text for the courses. However, the high schools quit using the OZ text toward the end of the year in order to prepare their students for the AP exams.

3.2 CCC Computer Projects

At CSTCC, we are developing computer laboratory projects which are part of the course. Only the first computer assignment is worked on during class. In this case, class is held in the computer laboratory, and students work in groups of two or three on a Warmup lesson designed to introduce them to the basics of Microcalculus or Derive and to show them the importance of using parentheses correctly. In this warmup lesson, students are led through a set of directions designed to get them to graph the rational function $f(x) = \frac{x+1}{x-4}$. After students have graphed the function, they compare their graph to the four shown on the laboratory sheet. Three of the graphs on the laboratory sheet are wrong—the result of keying $x+1/(x-4)$, $x+1/x-4$, or $(x+1)/x-4$ instead of $(x+1)/(x-4)$. The warmup activity is probably going to be less important as students become more familiar with their calculators.

Since each student has a graphing calculator, calculators are used for in-class activities. Students can easily graph or evaluate the most complicated functions. In addition, we have a set of worksheets that were designed for the *TI–81* by another mathematics faculty member at CSTCC. These workshops are at the precalculus and calculus levels. Each has a theme (such as limits) and contain specific keystrokes and/or a *TI-81* program.

Examples of the types of computer labs that we have used are given below. Notice that some of them serve "double duty" by reteaching some precalculus concepts.

- Translations/Effect of changing the coefficient of the x-term in a quadratic
- Introduction to limits
- Solving equations and inequalities
- Solving rational functions, limits
- Multiple derivatives and their graphs
- Numerical integration
- Taylor/Maclaurin series

- Graphs of sequences

4 Western Appalachia Calculus Consortium (WACCO)

The Western Appalachia Calculus Consortium (WACCO) project is headed by the University of Kentucky. WACCO was funded in 1992 by the National Science Foundation (NSF), Division of Undergraduate Education, and is composed of nine schools and includes, in addition to the University of Kentucky, five other Kentucky schools—Northern Kentucky University, Transylvania University, Eastern Kentucky University, Campbellsville College, and Cumberland College; one Virginia school, Ferrum College; and two Tennessee schools, UTC and CSTCC.

The main functions of the WACCO project are to share the identification, acquisition, and evaluation of approaches and materials that can be used to aid in the implementation of calculus (and precalculus) reform. This is being done by directly sharing opinions and experiences as well as materials developed and adapted at one site with others. We share materials in three major ways: (1) twice a year the consortium members meet to discuss their individual progress and concerns as well as to share materials being developed and used at the various schools, (2) an Internet-accessible archives of materials has been established, and (3) a journal is being developed.

Since the experiences of materials used, and approaches taken by different members of the consortium are quite diverse, this serves to broaden the base of information from which all members can draw. For instance, four of the schools are using the St. Olaf text and the others are using various other traditional calculus texts. The types of technology being used for classroom instruction include calculators as well as Maple, Mathematica, Microcalculus, and Derive. The common thread is that each member of the consortium, regardless of what text or technology he or she is using, is seeking to develop a calculus course in which conceptual understanding and problem solving are emphasized and "cookbook calculus" becomes a thing of the past. All the schools are introducing calculus reform into their first year calculus courses with different ones extending the same type of reform into an additional course such as linear algebra, differential equations or multivariable calculus.

Not only are the various schools using different texts and different approaches but are employing the use of various calculators, computers, and software packages. The total collection provides a very rich and diverse assortment of materials from which others can draw. The University of Kentucky is serving as a communications hub which provides an Internet accessible electronic library site for consortium materials.

4.1 WACCO Archives

Materials developed by consortium members are also sent to the University of Kentucky in electronic form via Internet and placed into an archives which can then be accessed by others through Internet.

One of the biggest problems in sharing materials has always been the problem of incompatibility between computers and word processors used to produce the materials. To solve this problem members of the consortium produce all materials using LaTeX. These materials are then sent to the University of Kentucky in electronic form via Internet and placed into an archives which can be accessed by others through Internet. When someone wants to use a file from the archives, it is retrieved as a text file and then processed and printed by LaTeX. This makes it easy for the recipient to edit the file for his or her own use without having to retype the entire document. Anyone with Internet can access the WACCO archives as described below.

How to access the WACCO Archives:

e-mail:	ftp ftp@ms.uky.edu
Login as:	anonymous
Password:	your e-mail address
Locate date in:	pub3/calculus
Cost:	$0.00

One result of using the archives is that members of the consortium are able to easily adapt materials from other members of WACCO, even though various members of the consortium are using different texts, approaches, and forms of technology as teaching aids.

4.2 WACCO Journal

The consortium is employing several other methods for dissemination and sharing of ideas and materials as well as encouraging others to participate in the sharing. We are publishing a journal where secondary school teachers and college/university level teachers can contribute articles where they share their ideas and experiences with mathematics curriculum and technology reform. The first issue of the journal, called the Appalachian Journal of School and Collegiate Mathematics, is due to be released around November 15, 1993. Anyone can get a copy of the journal via Internet

How to order the WACCO Journal:
Amount: $0.00
Order from:
Ms. Betty Griffin
Mathematical Sciences
% Department of Mathematics
University of Kentucky
Lexington, Kentucky 40506–0027

To obtain a paper copy or MS_DOS diskette
with postscript file or LaTeX sources

e-mail:	ftp ftp@ms.uky.edu
Look in directory under:	pubs/calculus/journal
Find:	• TeX/LaTeX sources for journal issues • Postscript files

4.3 Workshops

Another of the major goals of this project is to provide workshops and share materials and experiences with other institutions in our own communities. For instance, last weekend a workshop was held for 100 Kentucky high school teachers. This past summer CSTCC and UTC combined efforts and provided a three-day workshop on calculus and precalculus reform for high school teachers in the Chattanooga area. Twenty teachers from fourteen Georgia and Tennessee high schools attended the UTC/CSTCC workshop. The workshop had three components: (1) discussions, (2) hands-on use of technology, and (3) demonstrations of computer software.

During the discussions, we introduced participants to some of the new ideas and methods that are a part of calculus (and precalculus) reform, related our experiences with the OZ text, debated the proper role of technology, and encouraged participants to try some of the newer ideas, such as writing across the curriculum and cooperative learning. We specifically discussed some of the new approaches we have been using with the St. Olaf text as well as several of the new approaches that are applicable to precalculus courses.

Hands-on uses of technology provided participants with a chance to try out some of these ideas and techniques using the new *TI–82* calculators that we were able to purchase from the WACCO grant funds and present to them. (At the time the workshop was held, the *TI–82* had not been released. Texas Instruments loaned us a "classroom set" to use during the workshop. We then supplied the teachers with their own *TI–82* a few weeks later.) Many of the participants had been using the *TI–81* calculators in their own classes and could share ideas, programs, and techniques with each other. The workshop was conducted in the "hands-on" style using the method of learning through collaboration. This mirrored the approach to learning that is advocated by the reform movement as well as consistent with the new NCTM standards. In addition to the large amount of time spent using graphing calculators, teachers were given opportunities to use Maple, Microcalculus, and Mathematics Plotting Package (MPP).

Demonstrations were given on Derive and the use of Internet. Our area high schools will soon have Internet available through the computer science department at UTC. Each participant was given a 300+ page notebook. Among the items in the notebook were *TI–8x* lessons for precalculus, *TI–81* laboratory lessons, calculus computer laboratory lessons, documentation for MPP, and a disk containing the Mathematics Plotting Package, which is shareware available from Howard Lewis Penn in the Mathematics Department, US Naval Academy, Annapolis, MD 21402 (send two blank, IBM formatted disks). We had one follow-up meeting this Fall in which members of the workshop shared projects and assignments they had used with their students. Additional follow-up sessions will be held throughout the school year.

CSTCC's individual contribution to the WACCO project has been to continue to develop and test materials designed for use in our Calculus I & II classes as well as to begin to develop materials that can be used in our differential equations course to extend the ideas of conceptual understanding and problem solving into this course.

5 Differential Equations

At Chattanooga State we have been working on revising the elementary differential equations course and developing and testing materials for use in that course. What we have tried to do is to extend the ideas of conceptual understanding and problem solving into this course. The major emphasis is to steer the students away from rote memorization of techniques to a more meaningful understanding of differential equations and their usefulness. We are using the Giordano & Weir text. It takes a modeling approach to differential equations which was already a step in the right direction.

To go along with the text, laboratory exercises are being designed with three things in mind (1) to cut down on the amount of time that is actually spent in simply finding a solution to a particular equation, (2) to try to get the students to discover and explore concepts as we have been doing in the first year calculus course, and (3) to give students a chance to see the role that differential equations play in various situations and different disciplines.

For example, in the first lab the students use Derive to construct direction fields for several differential equations At this time we have not yet studied any solution techniques. All they have to do is to be able to get the equation into the form $dy/dx = f(x,y)$. Derive has a function that will graph the direction field. Derive simplifies the direction field function and comes back with a matrix of 2-component vectors. This enables the students to see that the vectors in the direction field are determined by actually approximating the value of the derivative at various points. Then by plotting these vectors they see the resulting direction field. Students were then asked to analyze the direction fields and discuss characteristics such as equilibrium points and stability. They were required to give all answers in complete sentences just as they do in the first year calculus projects.

In order to impress upon students the relationship between a differential equation and its solution they are asked to draw in several solution curves on the hard copies of their direction fields. Of course in some instances they had no trouble but others were rather frustrating for them. So we went back to the lab and superimposed the graphs of several solutions. Remember that this was during the first few days of the course and the students did not yet know how to solve the equations themselves. We called upon Derive to solve the equations for us and then substituted different initial values into the solution to produce several different solution curves to be graphed.. This helps reinforce the idea of how the direction field is related to the family of solution curves because they can see how the solution curves fit so beautifully on the graph of the direction field. It also seems to make a much bigger impression on them because they do it themselves rather than just looking at similar examples in text.

We also tried to use the computer when possible to let students discover some things for themselves as we have done in calculus. For example, before second order differential equations were introduced in class the students worked on a lab in which it was suggested that they assume a solution of the form $y = e^{rx}$. Then they substituted it into various second order homogeneous equations with constant coefficients and solved for the value of r. After doing several of these, they were to generalize their results and try to devise a quick way to find the values of r for a second order equation. They also had to explain why a quadratic equation that mirrored the differential equation itself would give roots that indicated the correct powers of

e^x that would satisfy the differential equation.

We also used Derive to aid in the solution of higher order equations using the method of undetermined coefficients. Here again the computer was used only as an aid in various steps of the process. The idea was that the students could concentrate on the process and not get lost in all the tedious differentiation and substitutions. For example if the equation is entered as a formula, then after the form of the particular solution has been determined it can be substituted into the formula and the results compared to the forcing function. Now it's up to them to find the undetermined coefficients. After equating the coefficients and setting up a system of equations, they could have Derive solve the system. Also they could solve more difficult equations such as third, fourth, or fifth order, etc. that there was never enough time (or patience) for in the past. However the most important thing here is that the CAS was not solving the equation for the student but the student was simply using it to perform certain specific tasks involved in the solution process. The student was clearly in charge; the CAS was only a tool.

We used the computer to save time on various steps of virtually every technique in differential equations but in no case would Derive ever solve the entire equation. So the student was always in control of the overall process and it seemed to help them learn and remember the solution techniques instead of replacing their need to know the techniques. The computer also helped them see how differential equations equations could be used to solve various types of application problems such as those found in David Arney's *DERIVE Laboratory Manual for Differential Equations.* Students buy this manual along with their text. Arney's application problems are timely, the directions are clear, and in most cases students have to analyze the solution graphs to answer the various questions posed in the problem. This helps to pull together the whole concept of a situation whose model involves a differential equation and whose solution can provide so much information about the situation.

6 Conclusion

Over the past two or three years we have seen an increased interest from all members of the mathematics department in using technology to enhance the teaching of both precalculus and calculus. With the help of the technology available we are beginning to be able to steer students away from simple rote learning to a more meaningful approach of the study of mathematics in which they are able to discover and explore concepts as well as solve more realistic application problems.

Working with these consortia has benefited CSTCC in many ways.

- **Involved in calculus reform.** It's much easier to embark on unfamiliar ground if you do not have to do it alone, reinventing the wheel as you go. Each member of a consortium is able to share ideas and experiences as well as materials with the other consortium members. There is no denying that one of the main reasons many instructors are reluctant to introduce calculus reform into their courses is that it takes a lot of extra time to adjust to new pedagogical techniques and to use the technology that is an integral part of the reform movement. It also takes a lot of time to develop new instructional and testing materials. From the community college standpoint we were able to benefit from some of the work that has been going on in larger universities for several years, where traditionally research and development play a larger role than they do in the community college, and where they usually have access to a larger amount of more sophisticated equipment.

- **Had input into calculus reform.** The fact that we were one of the first field test sites for the Ostebee-Zorn text, has provided us with many opportunities to influence this particular aspect of calculus reform. This has happened through our feedback to the authors and through our participation in the summer workshops at St. Olaf.

- **Acquired a Maple site license.** It was through the WACCO consortium that we were able to get Maple at CSTCC as a part of a consortium license which gives all consortium access to Maple at affordable prices.

- **Shared the latest in calculus reform and technology with area high school teachers.** We were definitely able to offer more to the participants of our workshop this summer because of the combined efforts and resources of UTC and CSTCC. Through the St. Olaf project we have not only had the chance to personally meet and work with Arnold Ostebee and Paul Zorn, but to work with area high school teachers, who are educating our future students. If they can get students used to the idea that conceptual understanding is more important than learning a set of isolated techniques in mathematics, then we can take students a lot further in college level mathematics.

- **Acquired connections and used e-mail.** We were able to gain access to Internet through UTC, although, as of this Fall, CSTCC is now on Internet. This may not sound like such a "big deal," but it gave us a means to communicate with others around the country who are involved in calculus reform. If it had not been for the WACCO Project, we would not have begun using e-mail as soon as we did, and almost all of our communications would have been confined to intradepartmental messages.

- **Learned, and used,** LaTeX. While one of us has been using TeX and LaTeX for over three years, the other has not. Because of LaTeX we are able to share communications even though we have different machines at home and in the office, and the mathematics looks great, even when shared between machines. We are also able to acquire and share labs and other material with people from other campuses.