REVITALIZING MATHEMATICS WITH PROBLEM SOLVING, COLLABORATIVE LEARNING, AND THE TI GRAPHING CALCULATORS

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ABSTRACT

The Mathematics Department at Westchester Community College is fairly conservative. There are seventeen full time members of the Department and about fifty part time members. The Mathematics Department is known for its excellent teaching and its strong and traditional mathematics courses. It is therefore difficult for most of the faculty to consider making dramatic changes in teaching pedagogy. Aside from the periodic minor revisions of the mathematics syllabi, the mathematics curriculum has not undergone any extensive revision for years. Naturally, there is resistance in changing the traditional curriculum.

The computer algebra systems and the graphing calculators along with the curricular reform movement provided the impetus for change. Change takes time and strategies had to be developed to deal with the apprehensions and resistance to change. This paper will discuss how these technological wonders has energized the faculty over the years, the changes in pedagogy and assessment that is continuing to evolve, the implementation of several curricular innovations, and the continuing departmental examination and revision of curricular offerings

INTRODUCTION

These are exciting times in mathematics education. Many important issues are being addressed and debated. Curriculum reform and technology are changing the way we teach mathematics. The resurgence of interest in problem solving and the use of collaborative learning strategies contribute to the changing teaching/learning environment. There have been dramatic changes during the past ten years, not only in what mathematics is being taught, but also in how it is being taught from elementary school to college.

Change takes time. Those who want to implement any change need to deal with colleagues who are apprehensive and resistant to change. One obstacle to change is the belief that the

ongoing movement to revise teaching methods and curricula will result in watered-down mathematics. Some colleagues fear that our students will not have the mathematical skills necessary for our society and that mathematics majors will not have the experience necessary for upper level study.

I will share the experiences I have encountered and how I assisted my colleagues in the process of transforming our teaching of mathematics. I will discuss how technology and the mathematics reform movement have revitalized and energized the faculty at my institution, the strategies developed to overcome the resistance to change, the changes in pedagogy and assessment that is continuing to evolve, the implementation of several curricular innovations, and the continuing departmental examination and revision of curricular offerings.

WESTCHESTER COMMUNITY COLLEGE

Westchester Community College is one of the 30 community colleges affiliated with the State University of New York. It has a 200-acre campus located 20 miles north of New York City. Its enrollment consists of 11,000 full- and part-time credit students and 8,000 non-credit students. The Mathematics Department has seventeen full-time members and over fifty part-time members. In September 2000 four members of the department and two newly hired faculty members will form a separate Computer Science Department. This is the result of increasing enrollment in the computer science curriculum.

This is my twenty-fourth year at Westchester Community College. I am privileged to have worked with many colleagues and students in several successful mathematics projects. My main motivation was to maintain my excitement in teaching. I am not satisfied with doing the same thing year in and year out. I continually search for tools and strategies to achieve an optimum classroom environment. Since many students have some form of mathematics anxiety, I find ways to encourage them to develop their full potential in learning mathematics and help them handle difficulties that affect their learning.

MATHEMATICS REFORM MOVEMENT

Mathematics education is in transition and numerous reform initiatives in curriculum and teaching are underway. Computer algebra systems and graphing calculators, along with the curricular reform movement, provided the impetus for changes in what is being taught, how it is being taught, and how learning is being measured. Several publications were critical in fueling these changes. The National Council of Teachers of Mathematics (NCTM) publication of three landmark documents, the Curriculum and Evaluation Standards for School Mathematics (1989), Professional Standards for Teaching Mathematics (1991), and Assessment Standards for School Mathematics (1995) were very influential in transforming the K-12 mathematics education. These standards have been widely debated and accepted by the mathematics community and many groups with a stake in mathematics education.

To assist the NCTM in implementing these standards, the National Academy of Sciences established the Mathematical Sciences Education Board. At the college level, the National Research Council has also called for changes in the area of teaching, curriculum, and evaluation. These organizations and others such as the American Association for the Advancement of Science, the Mathematical Association of America, and the National Science

Foundation have joined the College Board in calling for a re-emphasis on mathematics and science instruction.

The NCTM professional standards recommended five major shifts in the teaching and learning of mathematics toward a classroom environment that promotes the development of every student's capability. We need to shift-

toward classrooms as mathematical communities—away from classrooms as simply a collection of individuals;
toward logic and mathematical evidence as verification—away from the teacher as the sole authority for right answers;
toward mathematical reasoning—away from merely memorizing procedures;
toward conjecturing, inventing, and problem solving—away from an emphasis on mechanistic answer—finding; and
toward connecting mathematics, its ideas, and its applications—away from treating mathematics as a body of isolated concepts and procedures.
To implement these shifts, teachers may have to change their beliefs about the nature of mathematics and how it can best be taught and learned.

The U. S. Department of Education has identified ten ideas that would be useful to teachers for making the fundamental changes needed to help each student achieve his or her mathematical potential. In 1993 Carol Lacampagne identified these ten ideas for transforming mathematics teaching and learning that are backed up by research or by promising practical experience:

1. All students can and must learn mathematics, which should serve as a "pump," not a "filter."
2. Teachers need to listen to students and to incorporate into their instruction what they learn from listening.
3. Students learn mathematics best when they construct their own mathematical understanding.
4. Students need to learn more and different types of mathematics.
5. Mathematical discussion should be a daily part of classroom activity.
6. Teachers need to become 'informed guides' to the learner.
7. Calculators, computers, and related technology can be effective tools in the teaching and learning of mathematics.
8. Students need to share learning experiences.
9. Curricular and pedagogical change in mathematics cannot occur without accompanying change in student assessment.
10. Lasting change takes broad support.

In 1995 the American Mathematical Association of Two-Year Colleges (AMATYC) published Crossroads in Mathematics: Standards for Introductory College Mathematics Before Calculus. The philosophy and spirit of this document have been endorsed by national organizations such as the MAA (Mathematics Association of America), NCTM (National Council of Teachers of Mathematics), and SIAM (Society for Industrial and Applied Mathematics); and many state and regional organizations such as NYSMATYC (New York State Mathematical Association of Two-Year Colleges).

The Crossroads philosophy suggests a decreased use of the passive listening encouraged by the traditional lecture method, individual pencil and paper drill of meaningless exercises, rote manipulation, tests and final examinations as sole assessment tools. The Crossroads and the reform movement encourage the use of technology to aid in concept development; diverse instructional strategies, such as interactive and collaborative learning; communicating in mathematics verbally and in writing; problem solving and modeling real-world situations; connecting mathematics with other disciplines; and using the numerical-graphical-symbolic-verbal approach to problem solving.

Funding became available from sources such as the National Science Foundation and many projects were initiated. Colleges and universities formed consortiums to develop and implement reform programs from developmental mathematics to calculus and beyond, such as the Long Island Consortium for Interconnected Learning and the Calculus Consortium based at Harvard University.

In 1999 AMATYC produced Crossroads in Mathematics: Programs Reflecting the Standards. It is a report of the impact of the Crossroads, a document published to provide information and to facilitate exchanges among constituents interested in the success of these efforts. To update and refine its Standards, NCTM produced the new Principles and Standards for School Mathematics (2000) with input from many diverse expert communities that bear some responsibility for mathematics education. It is available in print and in electronic form.

GRAPHING CALCULATORS

Since 1986, one of the most exciting technological advances that have impacted on mathematics education and reform in mathematics curriculum is probably the hand-held powerful pocket computer or graphing calculator. They are relatively inexpensive, very portable, and convenient to use. Bert Waits of the Ohio State University, one of the most influential proponents of the use of graphing calculators, cited graphing calculators as the greatest force for positive change in mathematics education today. Thomas Dick, among many educators, reinforced Professor Waits' opinion when he said: "A calculator with graphics capabilities opens up truly different ways of approaching mathematics. This point cannot be overemphasized; graphical calculators provide us with an opportunity to change our approach to mathematics instruction enough that students of the 1990's may view mathematics in ways fundamentally different than their predecessors."

The development of sophisticated computer algebra systems such as Derive and Mathematica changed the way computers are used to teach mathematics. These technological advances and the mathematics reform movement were the impetus for me to make some fundamental changes in the way I view the mathematics teaching/learning environment. Since I teach in a conservative mathematics department, I could not easily make dramatic changes in content, so I started to make some changes in the way I teach and organize my lessons.

TECHNOLOGY GRANTS

It was my participation at the Second Annual International Conference on Technology in Collegiate Mathematics (ICTCM) in 1989 that sparked my interest in using technology to help students learn mathematics. I consider the ICTCM, NCTM, and AMATYC conferences

three of the best conferences for mathematics teachers to attend where one can learn about the mathematics reform movement, the impact of the reform, and how technology is changing mathematics education at all levels. It is also where one can learn how to use the latest technology to enhance the teaching of mathematics. I was enthusiastic about learning and experimenting with these new technologies.

I quickly found out that the only way to accomplish what I wanted to do was to write grants. So I applied for grants to establish and equip our Math Computer Lab and to pilot the use of graphing calculators in teaching mathematics. It took a lot of research, planning, talking, writing, organizing, and hard work to get funding. A Vocational and Applied Technology Education Act (VATEA) grant equipped our Math Computer Lab. I planned, designed, and ran the lab. Due to lack of classroom space, the lab is also a regular classroom and this limits its availability to students. No funding was available for a technical assistant. I did secure additional funding from the college to purchase the furniture, drapes, carpeting, software, and a large screen television for computer projection.

To encourage the use of graphing calculators in the classroom, I wrote grants to supply seed money to buy the calculators. I received funding from Westchester Community College, VATEA, and the WCC Student Senate to supply a classroom set of TI 81, then TI 82, and TI 85 graphing calculators to rent to students who could not afford or do not want to purchase their own calculators. The graphing calculator that we use allows students to see mathematics in a new light; it allows them to learn mathematics not just analytically but also graphically and numerically. It allows students to explore and test their conjectures easily. It allows students to investigate and solve non-contrived real life applications. To share what I learned, I conducted workshops for interested faculty and students. I believe this sparked the fire that continues to burn today in many of my colleagues.

CALCULATOR LOAN PROGRAM

I ordered the calculators, developed and administered a calculator rental program. The students who already had their own graphing calculators were allowed to use them. Those who opted to rent were required to sign a calculator rental contract. The rental income was used to purchase new calculators. The program worked well for students who stayed in their math courses; in fact, most of them decided to purchase the calculator by paying the balance at the end of the semester. For those students who withdrew or dropped out of the College, it was more difficult to get the calculators back even after repeated phone calls. As a consequence, I started collecting a deposit along with the rental fee. Students get their deposit back when they return their rented calculators after the final examination. Three colleagues requested that I extend the program to their students and so I did. The College administrators eventually recognized that this was a valuable service to the students and the bookstore took over the rental program in the fall 1995 semester.

GRAPHING CALCULATOR CLUB

To help students learn how to use this powerful but complicated technology effectively, I organized the Calculator and Computer Club. I recruited colleagues as Co-Advisors and our Mathematics Scholarship recipients to assist as peer tutors. I selected, trained, and supervised the scholars to assist other students and be available during the club meeting. The Calculator

& Computer Club had three Mathematics Scholars who assisted other students during the 1999-2000 school year. We conducted workshops and help sessions. The club usually meets on Wednesdays from 11:00 a.m. to noon during common hour (no classes are scheduled from 11:00 to 1:00 pm for Student Senate meetings, student club activities, and Faculty Senate meetings.)

DEPARTMENTAL REVITALIZATION AS A GOAL

Many articles and reviews of research on graphing calculators and computer algebra systems attest to the benefits of a technology-enhanced curriculum. I shared with colleagues the recent developments in the math reform movement and articles on graphing calculators. Colleagues saw my enthusiasm and the positive effects on students. The word spread and feedback from students was generally positive. The graphing calculators started to generate some excitement and enthusiasm among our students and faculty. A few colleagues started going to conferences and using graphing calculators. To further encourage colleagues to experiment with this technology, I applied for the Texas Instruments grants and received graphing calculators equipped with LCD panels for classroom projection. These were distributed to colleagues who wanted one and indicated an interest in using them in teaching.

Since 1992, I have required graphing calculators in my Pre-Calculus and Calculus classes. I encouraged students to learn features of the calculator as needed. I assigned group projects to my students to encourage them to work collaboratively on challenging problems. The students resisted doing the projects at first but later admitted they enjoyed working together. The majority of our students have jobs but they found ways to get around their work and class schedules to complete their projects.

Students can come to the Calculator and Computer Club meeting and get help with their math projects. Some students continue to meet regularly and study together even after their projects are completed. Although projects are time consuming to do as well as to grade, I still plan to use them and to continue to find other strategies to encourage students to work collaboratively. Some colleagues at Westchester Community College started considering changes in the way they taught mathematics. The tutors in our tutorial center became excited about learning to use technology to help students learn mathematics. My students started discussing mathematics with their classmates and friends.

In my spring 1994 Calculus I class, the students agreed to have their last group project written up and presented in class. The Media Center agreed to videotape these presentations. Each group presentation was for ten to twelve minutes and incorporated the use of the TI 85 in solving a problem. It was a worthwhile experience for everyone.

At WCC I teach traditional college students as well as the non-traditional students. In 1995 I was invited to teach and help develop an innovative Telecommunications Associate Degree program for New York Telephone company employees. The students were provided free tuition, one day a week off to attend classes all day, and all other college expenses including a laptop computer. It was a challenge and exhilarating to teach mature adults, many of whom have been out of school for over twenty years. During their second course with me I asked them to write a paper on any topic that involved an application of the mathematics we covered. They had to work in groups, incorporate at least one piece of software such as

Derive, Excel, or PowerPoint, and give a ten-minute presentation on the last day of class. They resisted doing the project at the beginning, even though the ability to communicate and work with other people was one of the umbrella competencies they were required to master. They came up with a variety of topics and I held a series of consultations with each group. They collected data on things like the statistics of baseball players, election results, or things that they do at work. Some solved mathematical problems and wrote about their group process: what responsibilities each one took, why they selected these problems, and how they went about solving them. They handed in a hard copy of their paper and a diskette. I was impressed by the quality of their work and their class presentations.

In 1996 I had the pleasure of assisting the Mathematics Department in instituting the use of graphing calculators in all upper level courses and selected computer software in some courses. Faculty interest for training in integrating graphing calculators increased. I applied for and received a grant to coordinate the Ohio State University Technology Summer Short Course at WCC. This grant provided for an instructor to come on campus. In June 1996, thirteen of our faculty, two high school teachers, three colleagues from area colleges, and two of our student tutors were among the first short course participants. I anticipated the need for support and a forum to discuss problems and exchange teaching tips and strategies. During the fall 1996 semester, I planned and coordinated a series of workshops and discussion sessions for faculty to help each other deal with issues involved in integrating the TI 85 in our courses. I provided handouts and created a folder of materials to share.

Colleagues became interested in using the Math Computer Lab/Classroom so that I could schedule only two of my own classes there. This provided the impetus for the department to write a proposal to equip another classroom with computers. More colleagues are attending professional conferences and discussing issues such as the need for faculty training and syllabi revision.

In May 1999, I again applied for and received a grant to coordinate the Ohio State University Technology Summer Short Course at WCC. Twenty faculty and tutors participated to learn about the TI 86. I continue to develop, revise and share materials for new models of the graphing calculators. I continue to do these activities without additional compensation because I believe in providing faculty and students with the necessary tools and support the use of these tools effectively in order to recharge, revitalize, and change.

I try to keep abreast with the changing technology. As new models come on the market practically every year, I continue to apply for the Texas Instruments grants to provide faculty with graphing calculators with a view screen to project images on the overhead projector. I have received over $30,000 worth of graphing calculators and ancillary materials. In addition, I also provided interested faculty with the new TI 89 and the TI 92. The TI 92 has a version of Derive software built into the calculator. I assisted students and colleagues in the use of these tools by coordinating, developing, or conducting workshops, tutorial programs, mentoring, etc.

It took seven years and today I can say that every full time member and many adjunct faculty of the Mathematics Department have embraced the use of some technology. A number of computer software programs are now being used in several courses. The TI 83 is required in Statistics and Contemporary Math classes. In the fall 1999 semester we started to phase in the

TI 86; it will eventually replace the TI 85 in all upper level courses. In the Fall 2000 semester the TI-83 will be required in all our College Algebra classes. Technology has changed the way we teach dramatically; everybody wants to teach our courses now with these wonderful tools.

REFLECTIONS

Teaching is a wonderful profession. Innovative projects have kept me excited about teaching. My involvement with technology and mathematics reform has inspired me to have several articles published. I enjoy sharing what I have learned with colleagues. In addition to leading numerous computer workshops and graphing calculator workshops, I also give presentations on various topics at local, national, and international conferences. In November 1999 my colleague Rowan Lindley and I presented a paper on "Experimenting with Reform in College Algebra" at the Ninth Annual International Conference on Technology in Collegiate Mathematics in San Francisco. This paper was based on the work we did with two other colleagues at Westchester Community College, Mel Bienenfeld and Sheela Whelan. On March 18, 2000 I gave a presentation/workshop at the Annual Ten County Mathematics Conference held in Pougkeepsie, New York. My session on "Using the TI 83 to Enhance Problem Solving" was the only session that was oversubscribed. It generated so much interest that I had to give two sessions to accommodate the number of participants.

I believe in using graphing calculators as a tool to enhance the teaching-learning experience, empowering the learner, investigating and exploring problem solving symbolically, graphically, and numerically. I wanted students to have a deeper understanding of mathematics and to play around with ideas and ask "what if" questions. Students with graphing calculators tend to explore more and investigate alternative solutions to problems. Why not build on this experience and use it to make mathematics more practical, more alive, and more fun? Looking at mathematics differently and developing lessons with technology has revitalized my teaching and hopefully helps students enjoy the lessons. The combination of using graphing calculators and collaborative learning activities in problem solving contribute to a dynamic and effective learning environment.

A number of challenges need to be addressed. The mathematics department is fairly conservative and the content of our course offerings are traditional. It will take some time to make additional changes. We have implemented some reform ideas in varying degrees in our courses such as College Algebra, Contemporary Math, Precalculus, and Calculus. The high failure and withdrawal rates are a concern to faculty as well as meeting the needs of students and the curriculum. The faculty is frustrated with the students' lack of preparation and poor study skills. The syllabus is packed and it is difficult to find sufficient time to fully integrate technology. Moreover, not many students regularly attend the help sessions and workshops.

However, there is progress in faculty discussions on using technology and on teaching methodology. There is promise in the use of the exploratory and investigative mode of approaching problem solving and collaborative learning through group projects. The graphing calculators allowed more lab type exercises for students to learn to make mathematical observations and to draw conclusions. These types of exercises can be started in class and finished as homework. For example, students make changes in different parts of a function, observe what happens to the graphs, and draw their own conclusions. Students are

able to look at two or three graphs on the same screen and come to some conclusions about the functions represented by these graphs. This is very difficult for students who are not used to experimenting and conjecturing in mathematics. They want to wait to come to class and ask the teacher for answers. We can try to pique their curiosity so that they will experiment on their own, learn to ask good questions, conjecture and test them out, and hopefully come to some reasonable answer or answers.

The Mathematics Department continues to be involved in a dialogue on improving our courses. For example, at our last department meeting, we started discussions on the changes in content we need to consider in updating our mathematics syllabi and alternative assessment methods. We have fully integrated the use of some technology in most of our courses. Some colleagues are working on websites and giving assignments on the Internet. I am currently working on integrating technologies such as CDROM, web based mathematics materials, and PowerPoint classroom presentations to enhance the teaching/learning process. These are powerful tools for teaching and learning mathematics.

I enjoy the challenge of learning new things and finding innovative ways to do things. I am gratified that the work I love has received wide recognition. I am honored to receive many awards such as the 1999 New York State Association of Two-Year Colleges Outstanding Contributions to Mathematics Education and the 2000 Westchester Community College Center for Faculty Risk Taking and Innovation Award. I am pleased to have a part in recharging our faculty, revitalizing our mathematics courses, and in the ongoing transformation of the teaching/learning environment.

We need to continue to evaluate what we teach and adapt our teaching methods to the changes in the way mathematics is being taught today.