Technology in School Mathematics:
A Course for Prospective Secondary School Mathematics Teachers

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Introduction

During spring semester 1995, a new course for prospective secondary school mathematics teachers, Technology in School Mathematics, was offered at Middle Tennessee State University for the first time. MATH 331 is designed to enable prospective teachers of mathematics in secondary school to effectively integrate technology into the teaching and learning process. The content of the course focuses on the implementation of technology in mathematical content areas such as pre-algebra, algebra, geometry, trigonometry, probability, statistics, discrete mathematics, and calculus, and the associated instructional strategies and mathematical pedagogy. It is required of all mathematics majors seeking a license to teach mathematics in grades 7-12.

Objectives

Upon completion of the course, students will have:
1. Enhanced skills and knowledge through the review and use of technology specifically related to teaching and learning mathematics
2. Been informed of the utility of technology in achieving the goals outlined in the NCTM *Standards*
3. Experienced guiding the mathematical learning process using technology
4. Gained information about current nationwide efforts concerning the integration of technology into mathematics instruction and the growing body of associated research
5. Been engaged in experiences of evaluating mathematics-specific technologies for possible use in the classroom.

Topical Outline

The course is loosely organized along the theme of the roles of technology in mathematics teaching and learning. Specifically, the roles of technology as an aid in mathematical concept and skill development, as an aid in mathematical problem solving, as a aid in mathematical reasoning, and as an aid in mathematical communication are emphasized. Consider the following topical outline of the course:
1. Role of technology as an aid in mathematical concept and skill development

    a. Enhanced power to deal with multiple representations via technology (e.g. symbolic, numerical, and graphical representations of functions in algebra)

    b. Enhanced ability to visualize via technology (e.g. manipulations via software packages of 3-dimensional objects such as solids of revolution by calculus students or by junior high students as an aid in developing spatial visualization skills)

    c. Enhanced opportunity to construct mathematical knowledge via individual and group investigation using technology (e.g. discovery of geometric properties by junior high students via geometry software)

    d. Enhanced opportunity for individualized and customized diagnosis, remediation, and evaluation (e.g. computer-aided instruction for algebra students having difficulty with factoring)

2. Role of technology to an aid in mathematical problem solving

    a. Enhanced ability to focus on the process of problem solving instead of the computational aspect (e.g. calculus students using a computer algebra system to perform numerical integration as one step in a multi-step applied problem)

    b. Enhanced ability to solve realistic problems instead of being restricted to contrived problems having "nice" solutions (e.g. algebra I students solving a problem whose model is a cubic equation via the aid of the graphing calculator)

    c. Enhanced opportunity for students to be introduced to interesting problems and associated mathematical subject matter much earlier than before possible (e.g. junior high students solving optimization problems via computer or calculator generated graphs, or estimating probabilities via computer simulations)

    d. Increased opportunity to develop mathematical modeling skills (e.g. junior high students programming a computer to model a card hand using integers and thus calculate expected values of carnival games involving card hands)

3. Role of technology as an aid in mathematical reasoning

    a. Enhanced ability to gather data in order to form conjectures and apply inductive reasoning (e.g. use of a calculator by junior high students to find number patterns)

    b. Enhanced motivation to think logically in order to program a calculator or computer to perform a desired task (e.g. secondary school students studying discrete mathematics programming a calculator to investigate the solution of a difference equation)

4. Role of technology as an aid in mathematical communication

    a. Enhanced motivation to communicate mathematics precisely in order to perform a desired tasks (e.g. algebra I students programming a computer to estimate the probability that a quadratic equation has real roots under varying conditions on the coefficients)

    b. Enhanced ability for students to present mathematical ideas both orally and in writing (e.g. use of word processors to write reports which include

mathematical symbols, tables, and graphs, and use of multimedia
presentation programs to communicate mathematical ideas)

Certainly this is not a topical outline in the sense that these topics are "covered" in sequential order. However, these topics form the thread that runs throughout the entire course, and every activity is referenced to one of these topics.

Metaphors Permeating the Course

To emphasize the empowering role of technology in the teaching and learning of mathematics, the following metaphors permeate the course:

(1) Technology as a *private investigator* who gathers data to be used as a basis for inductive reasoning and conjecture forming;
(2) Technology as a *slave* who performs laborious tasks in order to leave more time for emphasis on concepts instead of computation, and whose labor will allow one to investigate more realistic problems;
(3) Technology as a *logical communicator* which when communicated with will force logical thinking and precise language;
(4) Technology as an ever-patient *tutor*.

What could be more empowering for a mathematics student than to have the exclusive services of a private eye, a slave, and a tutor?

Relationship of the Course to the Entire Program of Study

Beginning in the fall of 1995 mathematics majors preparing to teach secondary school mathematics must complete the professional program in Mathematics Education. In addition to an emphasis in Mathematics Education, the Department of Mathematical Sciences also offers emphases in Applications of Mathematics (Business, Statistics, Technology Tracks) and Professional Mathematics (Advanced Mathematics and General Mathematics Tracks). Each student majoring in the Department of Mathematical Sciences must complete the following core consisting of 21 semester hours: Calculus I, II, III; Foundations of Higher Mathematics; Linear Algebra; and Probability and Statistics. Each track consists of 15 additional hours of specified upper-level courses in the department and 12 hours of supporting coursework (either in or out of the department.) A single minor outside of the department is required.

The additional 15 hours of upper-level mathematics courses specified in the Mathematics Education track are College Geometry, Abstract Algebra I, History and Philosophy of Mathematics, and two approved upper-level mathematics electives. The 12 hours of supporting coursework are courses in mathematics pedagogy offered by the Department of Mathematical Sciences, specifically **Technology in School Mathematics**, Teaching Mathematics in Grades 5-8, Teaching Mathematics in Grades 9-12, and Topics in Secondary School Mathematics. Prospective teachers must also complete **Introduction to Computer Science** (a programming course) and a minor in secondary education in the Department of Educational Leadership including a 2-hour senior seminar offered in conjunction with student teaching.

The minor in secondary education consists of the following courses: Education as a Profession, Psychology of Human Development and Learning, Survey of the Exceptional Child, Analysis of Effective Teaching, Methods and Strategies of Teaching, **Technology in Teaching**, Managing the Classroom for Instruction, Teaching Reading in the Content Area, and Directed Teaching.

Typically, students will take Technology in School Mathematics in the first semester of their junior year along with the middle school methods course. The following semester they will take the secondary school methods course. The prerequisites for Technology in School Mathematics are admission to teacher education, completion of the mathematics major core, the Technology in Teaching course which is a part of the secondary education minor, and Introduction to Computer Science. Since the latter two courses are required courses, they were made prerequisites to Technology in School Mathematics in order to take advantage of the foundation laid in those courses. In Introduction to Computer Science, students learn the fundamentals of a structured programming language. Technology in Teaching is a course in the "use of hardware and software in the teaching/learning process. The computer and selected media delivery systems for teaching and learning along with the design and creation of inexpensive teaching and learning materials" are emphasized. Specifically, students learn applications of spreadsheets, word processors, presentation software, and authoring software to education. They learn to use equipment in 21st century classrooms in the state of Tennessee. So students come to Technology in School Mathematics having a basic knowledge of a structured programming language as well as the uses of hardware and software in education in general, with hands-on experience with each.

Technologies Emphasized in Technology in School Mathematics

The emphasis in Technology in School Mathematics is on mathematics-specific technologies and the application of these, as well as technologies learned by the students in the prerequisite courses, to the teaching and learning of school mathematics. Throughout the course prospective teachers become aware of the broad range of mathematics-specific technologies available to teachers of mathematics, and become proficient in the use of several of these. Graphing calculators, geometry discovery software, and computer algebra systems are emphasized. Thus, in the spring of 1995, students completed tutorials on the either the TI-81, TI-82, or TI-85 (with emphasis on contrasting these three calculators), Cabri geometry software, and the computer algebra system Maple. Students then gained experience using these technologies in simulated junior and senior high school settings in which appropriate methodologies were modeled. Students learned to program their graphing calculators with emphasis on using the programming feature for problem-solving and with emphasis on the utility of programming in forcing logical thinking and precise mathematical communication.

To fulfill a requirement that each pair of students complete two projects using technologies other than TI calculators, in the spring of 1995 students chose projects involving Tesselmania software, the computer algebra system Derive, Logo, the Math Explorer Calculator, software and associated methodologies for helping students improve spatial visualization (Gyrographics, The Right Turn, and The Super Factory), and Statistics Workshop. Other choices for projects involved the CBL (Calculator Based Laboratory), Geometry Sketchpad software, Geometry Supposer software, Technology-Intensive Calculus for Advanced Placement, Problem

Solving via Programming, Using Spreadsheets as a Tool in the Secondary Mathematics Classroom, and the Assessment Standards with applications to technology use. Students gained experience in guiding the mathematical learning process with the aid of technology by making presentations of their projects to the class. These presentations also served to acquaint the other students in the class with a broader range of technologies and appropriate uses in the classroom.

Activities Required of Students

In order to complete the objectives of the course, the learner to required to:

a. Attend class and participate in all class activities
b. Use technology in simulated junior high and senior high school settings in which appropriate methodologies are modeled by the instructor
c. Give presentations and complete projects designed to provide experience in teaching and designing courseware using technology
d. Compile a journal
e. Read library materials which concern technology in mathematics education
f. Evaluate mathematics-specific technologies.

Evaluation of Students

In the spring of 1995 the semester grade was determined by scores on two tests, a midterm and a final which counted 10% and 15% respectively. The midterm was composed of a couple of discussion questions concerning the *Standards* as related to technology and the constructivist view of learning, as well as a competency test on Cabri geometry software. The final was a competency test on using a graphing calculator. The two projects culminating in presentations counted 10% each. The remaining 55% of the semester grade was based on a journal. Students were instructed that EVERYTHING associated with the class was to go into the journal - classnotes, laboratories/assignments completed both in and out of class, summaries of and reactions to assigned readings, critiques of technologies as assigned, and a weekly diary of reactions to the course. The journal was checked twice during the semester.

Modifications for Future Offerings

In the spring of 1995, the new course proposal for Technology in School Mathematics was going through the official approval process for new courses within the university. So a trial run of the course was offered as a special section of Problems in Contemporary Mathematics. Since the new undergraduate mathematics major requirements did not go into effect until the fall of 1995 and the prospective teachers enrolled in the old program were not required to take Technology in School Mathematics, the trial run of the course was offered as an elective and prerequisites were relaxed. Eight students enrolled, two prospective middle school and six prospective secondary school mathematics teachers. Some of the students had completed a programming course and the Technology in Teaching course; others had not. Now that the course is required, prerequisites will be enforced. Thus the students will be better prepared, and more time will be available to achieve the goals of the course.

Technology I School Mathematics will be offered as Math 331 for the first time in the fall of 1996. It is anticipated that the enrollment will be approximately 20 students. In this case, all of the projects listed earlier will be completed by students, thus acquainting the students with more mathematics-specific technologies than those students who took the course in the spring of 1995. More attention will be devoted to the topic of how technology can aid in getting students ready for algebra using books by Demana and Leitzel. More time will be spent on probability simulations via a software package which has just come to the attention of the author - *The Probability Constructor* (Logal). In the spring of 1995, probability simulations had been approached strictly from the standpoint of the teacher or a student programming a computer or a calculator to produce them. Also, in the future, students will become acquainted with resources for mathematics teachers available on the Internet, and emphasis will be placed on assessment and the growing body of research concerning technology in mathematics education. Students will be required to spend more time reviewing middle and secondary school texts for their uses of technology. Students will be given more opportunity to guide the mathematical learning process using technology, as each student will be assigned one or more "mini-lessons" to teach. Each mini-lesson will count roughly 5% of the semester grade, thus reducing slightly the percentage given to the journal in the computation of the semester grade. The journal will be checked at least three times during the semester in the future. Finally, during the trial run of the course, students were asked to read 10 articles of their choosing concerning technology in mathematics education journals. In the future, some of these articles will be specified and these will motivate the classroom activities on occasion.

Reactions of Students

Students were required to keep a weekly diary of their reactions to the course. Specifically the syllabus instructed them to: "Include your frustrations, satisfactions, changes which you would like to be made, etc. This will be used to improve the course and to give the instructor feedback
concerning the attitudes of the class. Be honest! What you say will not affect your grade, but your failure to say anything or your failure to spend sufficient time in providing this feedback will affect your grade. In other words "everything's o.k." is not a complete weekly journal entry." Students suggested that in the future student presentations should not occur entirely at the end of the semester, but be scattered throughout the semester. They also requested that they get a list of their library assignments at the beginning of the semester.

Students were enthusiastic about the course, although the two prospective middle school teachers taking the course who did not have all the prerequisites showed some initial anxiety. Hopefully, students required to take the course in the future will be as enthusiastic as the eight students who chose to take it as an elective in the spring of 1995.

Consider the comments of one of the prospective middle school teachers taking the course. "I am finding the graphing calculator to be rather difficult to use. I am hoping that in class I can better understand how to use it." (January 18, 1995) "I am enjoying working with the geometry software, Cabri. I've never seen anything like it, so it is pretty amazing to me. I think middle school and high school students could learn a lot from it and have fun at the same time." (February 2, 1995) "I don't feel very confident about my mathematical knowledge or lack thereof in this class. I also feel somewhat uncomfortable with technology. My experience with it is quite minimal. I appreciate your working with me." (February 23, 1995) "I'm glad we used

the graphing calculator today. I'm not very familiar with it, so any work we do in class is helpful. It's unbelievable all the things you can do with it. Until this class, I had no idea that there existed a calculator with those types of capabilities. I found it interesting that a graph can change so much just by changing the range on the calculator." (March 2, 1995) "Doing the Advanced Techniques on the TI-82 was helpful. Naturally, the more work we do with the graphing calculator, the more comfortable I feel with it. I used to be so intimidated by it, but little by little, I'm beginning to have confidence in my ability to use it. As I work with the Cabri software, to do the macros, I'm liking it more and more. I have never been too confident in my ability to use computer software, but this is one that I feel like I can do. I think it would be wonderful for geometry students to use. It's not too difficult and they can learn a whole lot." (March 14, 1995)

Consider the comments of one of the prospective secondary school mathematics teachers taking the course. "I love the Gyrographics software! I think that it is great how you can graph a curve and let the computer rotate it for you. That was a very hard concept to learn in calculus, but this software makes visualization of the whole problem possible." (January 1, 1995) "We worked with the Cabri geometry software. I really like going through the tutorials supplied by the companies. It is fun to be able to work at a comfortable pace and explore the software to see what it can do. I am really enjoying this class because I will have to be able to incorporate technology into my classroom. This class is showing me what is available to be used and how to use what I've got." (February 2, 1995) "Since we did not have class on Thursday, we had to go to the lab in KOM 359 to work on the Maple software. We were in the 21st century classroom....I was very impressed and excited by the classroom....Jane *(a fictitious name)* and I got over half way through the lab and we will finish next Wednesday....We did learn a lot and we had fun!" (February 22, 1995) "Tuesday, I had a great time in class learning about the CBL. I had no idea that the labs had advanced so much. I could not believe how fast Dr. Lee *(guest speaker)* was able to bring up a new program, run it, collect data, and graph....I find that I get real excited about some things that we do in class - sometimes too excited, as I feel compelled to tell people about it even if they do not care or have a clue." (February 23, 1995) "I am getting stressed out and I am ready for the semester to be over. I like all of my classes (but history), but they all assign entirely too much busy work....Obviously, I do not want to spend my spare time, which is little to none, on campus in the library looking for more articles to review. I am sorry, but I am two papers shy of insanity. These thoughts do not reflect on this class alone, it is a combination of all." (March 9, 1995) "We did not have class today due to our meeting at Riverdale with an algebra II teacher. She told us how she incorporates technology in her class. She uses graphing calculators, as the school has a lot, but so do a lot of her students....She showed us their computer labs and I could not believe it. I could not believe how much technology was incorporated in that school. It was great....I wish we could have had more questions to ask her, but she answered just about all of mine in her talk." (April 25, 1995) "This has been a fun class as we have done some really fun and interesting things....The assignments were not very hard, but somewhat overwhelming at times. It would have been better to get them in smaller chunks with sooner due dates than 5 assignments with one due date for the next five weeks...The journal article reviews were not too bad, but should be included on the syllabus so the student can start right away instead of trying to cram when all kinds of homework is due in other classes....Also the presentations may be more effective if they are spread out with one a day for four weeks....All in all, I enjoyed the class and feel that it will be very beneficial to me when I start to teach. I bought a TI-82 for this class and did not have a clue how to work it. I

had no idea that it could do so much stuff-I love it and am no longer scared of it-my calculator or other forms of technology that I may be using." (May 3, 1995)

Textual Resources Used in Conjunction with Technology in School Mathematics

A single text which addresses a majority of the topics in the topical outline is not available. Students are required to read major portions of *the Curriculum and Evaluation Standards for School Mathematics*. In the spring of 1995 they completed tutorials from the *Graphing Technology Guide*, *Calculus with Maple V,* the Cabri manual, and one of the following*: Introduction to Programming on the TI-81*, *Introduction to Programming on the TI-82*, and *Introduction to Programming on the TI-85*. Students were required to read *How to Use Conjecturing and Microcomputers to Teach Geometry*. In addition, they completed activities from *Graphing Calculator Activities: Exploring Topics in Algebra I and II, Graphing Power: Middle School Activities for the TI-81 and TI-82, and Graphing Power: Middle School Activities for the TI-81 and TI-82*. Students compared *Concepts in Algebra: A Technological Approach* with more traditional algebra texts of their choosing. During the fall of 1996, students will also complete activities from *Getting Ready for Algebra: Level I* and *Getting Ready for Algebra: Level II*. The following books are among the references for the list of projects from which students can choose*: Using the Math Explorer Calculator: A Sourcebook for Teachers*, *How to Teach Mathematics Using a Calculator*, *Exploring Mathematics with your Computer, Mathematical Topics for Computer Instruction: Grades 9-12*, *How to Model It: Problem Solving for the Computer Age, Spreadsheets in Mathematics and Science Teaching*, *Spreadsheet Activities in Middle School Mathematics, How to Use the Spreadsheet as a Tool in the Secondary School Mathematics Classroom, Visualization in Teaching and Learning Mathematics*, and *Technology-Intensive Calculus for Advanced Placement.* Students are required to read articles from *Teaching Mathematics in the Middle School* and the *Mathematics Teacher.*

Resource List

Books

1. *Graphing Technology Guide.* Benjamin Levy. 1993. D.C. Heath and Company. ISBN: 0-669-34226-2.
2. *How to Use Conjecturing and Microcomputers to Teach Geometry.* Daniel Chazan and Richard Houde. 1989. NCTM. ISBN: 0-87353-279-1
3. *Introduction to Programming on the TI-81.* 1984. Texas Instruments, Inc.
4. *Introduction to Programming on the TI-81.* 1984. Texas Instruments, Inc.

5. *Introduction to Programming on the TI-81.* 1984. Texas Instruments, Inc.
6. *Concepts in Algebra: A Technological Approach.* The University of Maryland, The Pennsylvania State University. James T. Fey, Mary Kathleen Heid et. al., Contributing Editors. 1995. Jansen Publications. ISBN: 0-939765-73-X. (Comes with a disk.)
7. *Using the Math Explorer Calculator: A Sourcebook for Teachers.* Gary G. Bitter and Jerald L.Mikesell. 1990. Addison Wesley. ISBN: 0-201-23389-4.
8. *How to each Mathematics Using a Calculator.* Terrence Colburn. 1987. NCTM. ISBN: 0-87353-245-7
9. *Graphing Calculator Activities: Exploring Topics in Algebra I and II.* Charles Lund and Edwin Anderson. 1992. Addison Wesley. ISBN: 0-201-29091-X.
10. *Graphing Power: High School Activities for the TI-81 and TI-82.* The Graphing Technology in Mathematics Project. 1995. Dale Seymour Publications. ISBN: 0-86651- 827-4.
11. *Graphing Power: Middle School Activities for the TI-81 and TI-82.* The Graphing Technology in Mathematics Project. 1995. Dale Seymour Publications. ISBN: 0-86651-827-4.
12. *Getting Ready for Algebra: Level I.* Franklin Demana and Joan Leitzel. 1988. D.C. Heath and Company. ISBN: 0-669-15710-4.
13. *Getting Ready for Algebra: Level II.* Franklin Demana and Joan Leitzel. 1988. D.C. Heath and Company. ISBN: 0-669-15710-4.
14. *Exploring Mathematics with Your Computer.* Arthur Engel. 1993. Mathematical Association of America. ISBN: 0-88385-639-5. (Comes with a disk.)
15. *Mathematical Topics for Computer Instruction: Grades 9-12.* Harris S. Shultz and William A. Leonard. 1990. Dale Seymour Publications. ISBN: 0-86651-501-1 Order No.: DS01012.
16. *How to Model It: Problem Solving for the Computer Age.* Anthony M. Starfield, Karl A. Smith and Andrew L. Bleloch. 1990. McGraw-Hill, Inc. ISBN: 0-07-005897-0.
17. *Using the Spreadsheet as a Tool in the Secondary School Mathematics Classroom..* William J. Masalski. 1990. NCTM. ISBN: 0-87353-303-8. (Comes with a disk.)
18. *Spreadsheets in Mathematics and Science Teaching.* John C. Whitmer. 1992. School Science and Mathematics Association. ISBN: 0-912047-09-7.
19. *Spreadsheet Activities in Middle School Mathematics.* John C. Russell. 1992. NCTM. ISBN: 0-87353-343-7. (Comes with a disk.)
20. *Visualization in Teaching and Learning Mathematics.* MAA Notes Numnber 19. Walter Zimmermann and Steve Cunningham, Editors. 1991. MAA. ISBN:0-88385-071-0.
21. Technology-Intensive Calculus for Advanced Placement. C^3E Summer Institute. 1991. TICAP Project, Clemson University.
22. *Calculus with Maple.* Stan Devitt. 1993. Brooks-Cole. ISBN: 0-534-16-362-9.
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Software

Geometry:
1. **Cabri: The Interactive Geometry Notebook..**. Brooks-Cole.
2. **Cabri Geometry II**. Texas Instruments.
2. **Geometric Supposers**. Sunburst.

3. **Geometer's Sketchpad**. Key Curriculum Press.
4. **Logo**. Harvard Associates.
5. **Tesselmania**. Key Curriculum Press.

<u>Computer Algebra Systems:</u>

6. **Maple**. Brooks-Cole.
7. **Derive**. Mathware.

<u>Probability and Statistics:</u>

8   **Probability Constructor**. Logal.
9   **Statistics Workshop**. Sunburst.

<u>3-d Graphing:</u>

10 **Gyrographics**. Mathware.

<u>Spatial Visualization:</u>

11. **The Right Turn**. Sunburst.
12. **The Super Factory**. Sunburst.