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ABSTRACT

The potential uses of online communication in the preparation of preservice and inservice secondary mathematics teachers transcend the traditional geographic benefits of distance education. Not only can the technology provide asynchronous instruction over great distances, it may also be used to create genuine opportunities for keeping pace with rapidly emerging content, epistemologies, and pedagogical strategies associated with contemporary mathematics. In other words, computational technology is reinventing mathematics while simultaneously increasing opportunities and raising expectations for the learning of mathematics. Mathematics educators will benefit from these technologies via the ability to personally construct mathematics, cope with the rapid pace of mathematical innovation, discuss the pedagogical issues associated with these changes within an expanded community of practice, and learn how technology may be employed to assist more students in a joyful pursuit of mathematical understanding. This paper offers a model for the development of online learning environments designed to prepare new teachers to teach secondary mathematics. The need for dynamic telecourses is discussed, along with features needed to ensure that prospective teachers not only learn new content but pedagogical strategies as well. One current online community, NetAdventure, is offered as a case study of what is currently possible. (Author)

Paper Session

Online Communities as a Vehicle for Developing Secondary Mathematics Educators

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This paper will offer a model for the development of online learning environments designed to prepare new teachers to teach secondary mathematics. The need for dynamic telecourses will be discussed, along with the features needed to ensure that prospective teachers not only learn new content but pedagogical strategies as well. One current online community, NetAdventure, is offered as a case study of what is currently possible.

Introduction

The potential uses of online communication in the preparation of preservice and inservice secondary mathematics teachers transcend the traditional geographic benefits of distance education. Not only can the technology provide asynchronous instruction over great distances, it also may be used to create genuine opportunities for keeping pace with rapidly emerging content, epistemologies, and pedagogical strategies associated with contemporary mathematics. In other words, computational technology is reinventing mathematics while simultaneously increasing opportunities and raising expectations for the learning of mathematics. Mathematics educators will benefit from these technologies via the ability to personally construct mathematics, cope with the rapid pace of mathematical innovation, discuss the pedagogical issues associated with these changes within an expanded community of practice, and learn how technology may be employed to assist more students in a joyful pursuit of mathematical understanding.

Online Telecourses

The increasing availability of Internet access (e-mail, newsgroups, MUDs, MOOs, the World Wide Web) makes low-cost, high-output professional development telecourses possible. In 1997 several interesting models already existed and telecourse development was underway. Robert Tinker suggests the following scenario for the future of online professional development for teachers:

> *There will be an explosion of network-based courses for teacher professional development. The best of these will offer world-class learning opportunities that will intermix cognitive research, educational philosophy, subject matter content, and just-in-time support for in-class experimentation. Participants can work with local study groups and larger virtual groups that span the world. The faculty leading these will consist of teams that include international experts, experienced teachers, and outstanding researchers. Graduate credit from leading institutions throughout the world will be available for teachers. Part of the teacher evaluation will be based on curriculum and research contributions participating teachers make and post on the network. The result will be a growing teacher-generated literature of immense value to education and increasing appreciation for the role of life-long learning for teachers and teachers who are also researchers making contributions to education, science, and mathematics.*
> *The availability of excellent graduate netcourses will substantially improve teacher preparation and professional development. With thousands of accredited courses available online, no teacher or prospective teacher will ever again have to suffer through a dull, meaningless course just because it is the only one available. That stuffy, old, sexist fogy, droning on from out-dated notes will have no audience. In fact, entire departments and schools of education will find themselves out of business unless they improve their teaching and scholarship, because their students will be recruited to stronger, more aggressive graduate schools throughout the world.*
> *(Tinker, 1997, p. 5)*

New Content, New Tools, New Ways of Knowing

Perhaps no subject of study bears as little resemblance to the discipline it intends to teach as mathematics education. The incongruity between pedagogy, content, and purposeful application occurs at a time when mathematics is changing rapidly. Mathematicians and scientists are alert to the blurring boundaries between different branches of mathematics and other disciplines, new ways of solving problems, and the increasing importance of mathematics in the social and behavioral sciences. The increasing demands of the behavioral and social sciences for reliable quantitative measurement and analysis of new types of problems not only relies on mathematics but also influences its development and teaching.

Much has been written about the societal demands for an increasingly mathematically literate population. We live in a world awash in data. Good citizenship is dependent on an ability to process often confusing and conflicting information. Economic, political, and social trends require students to have a much deeper understanding and appreciation for mathematical thinking now more than ever before. The pace of technological innovation spurs the rapid evolution of mathematics.

The NCTM Standards state that "fifty percent of all mathematics has been invented since World War II" (National Council of Teachers of Mathematics, 1989). Few if any of these branches of mathematical inquiry have found a home the K–12 curriculum. Topics such as number theory, chaos, topology, cellular automata, and fractal geometry may appeal to students unsuccessful in traditional math classes. These new areas of mathematics tend to be more contextual, visual, playful, experimental, and fascinating than the traditional emphasis on paper-and-pencil-based algebra and geometry. Technology provides an opportunity for more children to view mathematics as a powerful part of their own learning and to embrace the process of mathematical inquiry. As Papert (1980) has noted:

> *A dignified mathematics for children cannot be something we permit ourselves to inflict on children, like unpleasant medicine, although we see no reason to take it ourselves.*
> *(p. 54)*

Secondary mathematics teachers can and should explore these new mathematical domains. Prospective and practicing teachers should acquaint themselves with these new "ways of knowing" by using the actual technology that (a) led to the development of these new mathematical ideas and (b) will assist their students in the construction of personal meaning. The constructivist principle of learning through the making of connections is apparent when a teacher is using technology to learn about new mathematical knowledge that is itself the product of similar technology while thinking about how this technology might be used by students to construct understanding of a particular mathematical concept. Ongoing reflective practice and action research can play an important role in telecourses. Emerging technologies for sharing video over the Internet makes it possible to have a community of prospective educators to critique each other's teaching and even visit other classrooms.

The Concord Consortium (Tinker & Haavind, 1997) suggests that the advantages of telecourses include:

- Anytime, anywhere learning
- Asynchronous interaction
- Group collaboration
- New educational approaches
- Integration of computers

Rich online learning experiences encourage communication, community, collaboration, curiosity, courage, commitment, and common sense on the part of each participant.

NetAdventure: One Model of Online Learning

We believe that the successful online learning activities will combine communication, community, compelling content, context, computation, challenging problems, and a personal commitment to active learning. While our university is experiencing great success in creating online communities and courses to support practicing classroom teachers, new models of electronic communication need to be developed to educate preservice teachers.

NetAdventure, developed by the Concord Consortium (http://www.concord.org/netadventure), is but one vital example of how the World Wide Web may be used to support a community of mathematical inquiry. While NetAdventure is targeted at secondary school students, it is rich enough to engage young children and adults alike. The design and content of NetAdventure offers a powerful model of what might be built for adults studying to become secondary mathematics teachers.

Designed around the metaphor of a summer math and science camp for Grades 7–12, NetAdventure requires participants to join a group of explorers. Each week, a theme such as collecting/interpreting data on the Web or building a model is used to unify a daily area of exploration. The user is presented the topic of the day along with the opportunity to explore a previous topic. A list of the other learners participating in the adventure appears along with the names of expert guides who lead each "expedition." Each daily topic offers background information, an opportunity to share data, hypotheses and questions with fellow investigators, and three problems of increasing complexity. The goals of community and communication are satisfied through the list of fellow participants, the public postings, and the reminders to share your thinking with your fellow adventurers.

The topic of prime numbers is explored in exciting ways. The background information is concise yet thorough, and hypertext links to sites dedicated to prime number research are provided. Participants learn about prime numbers and why mathematicians think they are an important area of inquiry. An invitation for learning is offered through a historical context, interdisciplinary connections to chemistry, and playful motivation. The simultaneous notions of prime numbers being both beautiful and fun may pique the interest of even reluctant learners. Here is the invitation:

> *The study of prime numbers has fascinated people for eons, pursued for its own sake and the beauty of its results ... Unlike chemists that have only a hundred or so elements to play with, mathematicians have endless numbers in which to search for primes. They even know that there are endless numbers of primes. With so many numbers to play with, finding primes should not be difficult. However, prime numbers are scattered among the whole numbers in a seemingly unpredictable manner. See whether you can see any pattern to them.*

The "Starter Problem" presents the concept of separating prime and composite numbers through the rather simple Sieve of Eratosthenes. Even the youngest learners can cross out every second number beginning with four, every third number beginning with six, and so forth. The result is a list of prime numbers. The "Super Problem"—Can you prove the great mathematician Euclid of Alexandria wrong?—requires much more active thought.

Many learners would be excited by the challenge to knock down one of the great pillars of mathematics. Could I possibly be clever enough to "defeat" Euclid?

Euclid, who lived around 300 B.C., thought he had a formula that would always generate primes. He suggested multiplying together all primes up to a certain value and then adding 1. He thought this would always give a prime. Can you prove him wrong?

MicroWorlds, the latest generation of Logo software, can be used to write a handful of procedures required to test Euclid's hypothesis (Appendix 1). In just moments, the program finds that the prime number 13 does not satisfy Euclid's rules for predicting prime numbers. How could it be so easy to disprove such a great mathematician? Could this be that multiplying all of the prime numbers up to 13 was too difficult in 300 B.C.? Which numerical system did they use at that time in Greece? Could such a difference have made the problem harder to solve? Could Euclid have saved himself embarrassment if he had a computer with the MicroWorlds software? NetAdventure provides the ability to discuss these questions within an online learning culture. An adventurer can not only post data and conclusions for public scrutiny but also the program used in the investigation.

The ability to not only share data, experiences, and opinions online but also share actual verifiable executable experiments creates a dramatic new paradigm shift in thinking about online learning. Much of what is offered as online teaching consists of delivering content to students. We are not only stressing the importance of two-way online conversation but also the desire to have learners share resources, data, tools, and experiments with one another. The shift from instructionist teaching online to constructionist learning is critical for the personal construction of mathematical understanding.

The NetAdventure "Mega Problem" posed about prime numbers deals with prime factorization of large numbers. A poignant connection to real life is made by discussing how large composite numbers with two large prime factors are being used for credit card encryption on the Internet. An Excel spreadsheet designed to help find prime factors is available for download. This context would undoubtedly make the seemingly boring act of prime factorization more relevant to a learner. At last, the familiar question "When will I ever use this?" can be answered.

Once again, MicroWorlds is used to solve the challenges posed in a matter of minutes (Appendix 2). Each NetAdventure topic concludes by inviting participants to post their own challenge related to the current area of exploration.

Within a handful of Web pages, NetAdventure creates a community of practice, challenges individuals to construct new mathematical knowledge, supports communication of mathematical ideas, and provides a powerful context for learning through compelling storytelling, history, and connections to real life. One powerful lesson for contemporary mathematics educators is that a learner can hardly keep pace with three problems per day if the problems are authentic and open ended. This stands in stark contrast to the dozens of more decontextualized problems students face each day in traditional mathematics classes. Another lesson is that the process skills associated with the ability to think mathematically and communicate mathematical ideas should take precedence over the memorization of algorithms. If you are not fascinated by prime numbers, tomorrow's topic may be bridge building. The Swarthmore Math Forum (http://forum.swarthmore.edu/) and Tapped-in (http://www.tappedin.org) offer a tremendous range of resources for teachers and learners alike.

Existing telecommunications technology makes it possible to develop environments, similar to NetAdventure, designed to meet the specific needs of preservice and inservice mathematics educators. Online telecourses are cost effective and create outstanding opportunities to learn in an ever-expanding community of practice. Our efforts to develop such online learning communities will reap tremendous benefits for our universities and children enrolled in mathematics classes.

Appendix 1
Procedures for Testing Euclid's Hypothesis

The startup procedure resets the list of prime numbers and starts counting up by 2. Each subsequent number is checked by the countup procedure to see if it is prime. If it is, the new prime number is added to the primelist and printed alongside the Euclidean hypothesis of multiplying all the previous primes and then adding 1. The word "true" appears if the new number is PRIME, false if it is COMPOSITE.

The Macintosh version of MicroWorlds crashes after the number 29 because the product is too large. You may be able to test higher numbers in the Win 95 version of MicroWorlds.

The first number in the table is the most recent prime number found.

The second number is the product of all prime numbers to that point, plus 1.

The third entry indicates whether the new number is prime.

```
to startup
ct
make "primelist []
countup 2
end

to countup :number
if prime? :number [make "primelist
lput :number :primelist print
(sentence :number (productall
:primelist) + 1 prime? (productall
:primelist) + 1)]
countup :number + 1
end

to prime? :number
output checkprimes :number int (sqrt
:number)
end
```

Remainder is a Logo reporter that reports the remainder of two numbers when divided. For example, remainder 10 3 returns the number 1. If remainder returns 0, then the numbers are divisible and therefore composite.

```
to checkprimes :number :factor
if :factor < 2 [output "true]
if 0 = remainder :number :factor
[output "false]
checkprimes :number :factor - 1
end

to productall :list
if empty? :list [output 1]
output (first :list) * productall bf
:list
end
```

2	3	true
3	7	true
5	31	true
7	211	true
11	2311	true
13	30031	false
17	510511	false
19	9699691	false

The first number in the table is the most recent prime number found
The second number is the product of all prime numbers to that point, plus 1
The third entry indicates whether the new number is prime

startup

Click the button to begin trying numbers > 1 to check if the product of all previous primes + 1 is in fact prime as predicted by Euclid

Appendix 2

Procedures for finding the prime factors of any number.

```
to factor :number
make "factorlist []
ct
getfactors :number int :number
end

to getfactors :number :factor
if :factor < 1 [print :factorlist
stop]
if 0 = remainder :number :factor [make
"factorlist lput :factor :factorlist]
getfactors :number :factor - 1
end
```

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