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Bridging the Gap: A Mathematician's Challenge

By Laurie Burton

Given the shortage of mathematics educators and the MET document's call for expanded and enhanced course offerings, it is inevitable that mathematicians will be asked to teach some of the mathematics courses for future K–8 teachers. However, designing and managing successful courses for future K–8 teachers is more complex than a mathematician might, at first, imagine.

Training non-mathematics majors to have a deep understanding of the K–8 mathematics curriculum is not simply a matter of teaching new mathematics content. Instead, the goal is to train future teachers to understand the structure, procedures and nuances of elementary mathematics. When I was introduced to the curriculum of K–8 mathematics education courses, I found myself facing new challenges and adjusting to a new set of teaching and learning objectives. I would like to share what I learned with mathematicians who wish to add the mathematical preparation of K–8 teachers to their teaching repertoire.

My Background

After I graduated from the University of Oregon with a Ph.D. in mathematics, I spent four years as a typical enthusiastic junior faculty member at a public undergraduate institution. I embraced reform methods, engaged my students in collaborative learning and was an active member of Project NExT. My interaction with education majors consisted of working with the future high school teachers in my classes and teaching summer graduate courses for in-service high school teachers. I enjoyed working with these teachers and found myself increasingly interested in the mathematical education of all future K–12 teachers.

I eventually had the opportunity to join the mathematics faculty at Western Oregon University and work in their "already exceeds the MET recommendations" teacher preparation program (we have twelve mathematics education courses designed specifically for K–8 teachers). As part of my new position, I became an OCEPT Fellow and was asked to update the curriculum for several of our K–8 mathematics education courses.

The recommendations that follow are based on my own experience teaching mathematics education courses. They are not meant to be exhaustive. They are simply ideas that a mathematician working with future teachers developed with the advice of practiced mathematics educators and quite a bit of trial and error.

Professional Development

Recommendation: Seek formal professional development opportunities.
As a first step, I attended conferences and workshops designed to facilitate effective teaching for teacher education courses. This intensive exposure to curriculum topics and presentation approaches opened my eyes to many of the instructional methods I would need to integrate into my own mathematics education courses. Professional development is now widely available to mathematicians interested in teacher education. The MAA, for example, is increasing their offerings of workshops for the development of teacher training skills in their PREP and PMET programs.

Recommendation: Seek the advice of experts.
I sought out and talked to noted mathematics educators at local universities. These colleagues were very helpful. They recommended curriculum and assessment sources and shared ideas about effective classroom design for future K–8 teachers. One colleague, for example, introduced me to an application of modular arithmetic appropriate for use with future K–8 teachers. This helped me to understand the level at which I should approach these students and piqued my interest as an algebraist.

Recommendation: Collaborate with your colleagues in the education department and join them in K–8 classrooms.
At my university I was able to find like-minded colleagues in the education department. We scheduled time together and coordinated the syllabi and the structure of the mathematics education content courses taught in the mathematics department with the mathematics pedagogy courses taught in the education department. Additionally, we occasionally visit local classrooms together, which provides me with a critical awareness of the mathematics my students will be expected to master and teach.

The Classroom and the Students

Recommendation: Use appropriate classroom models.
I first attempted to implement new teaching and learning strategies by presenting "mini-lectures" followed by collaborative group work. This did not work well. Merely presenting basic information to students who already know the details of elementary algorithms does not generate the critical thinking that leads to the lasting foundation of mathematical understanding these students need. With the help of experienced educators, I kept changing my instructional methods and procedures until I found a more successful approach. My current model for mathematics education class design is roughly as follows:

- To set the stage, I quickly target the main ideas of the lesson for the students.

- To encourage focused and active deliberation on the material, I supply in-depth, hands-on, visually supported collaborative activities. These explorations include questions about how the mathematics works and how one explains the mathematical topic under consideration. The students work in groups, often with manipulatives, and my

role is to constantly circulate, listen, answer questions, and solicit explanations.

- To follow up the group work, I use discussion and frequent (student) presentations of problem solving approaches. Future teachers see that a variety of solution paths often lead to the same conclusion and this helps to create flexible teachers. This also fosters verbal fluency in the explanation of mathematics concepts.

The goal of this class model is to allow the students to understand the content intuitively, to bridge to algorithmic approaches, to practice explaining mathematics and to create long-lasting meaning out of their course curriculum. Students in this type of course use their in-class work as a resource, successfully work out and explain problems, and demonstrate knowledge retention and in-depth understanding on exams.

Recommendation: Use appropriate curriculum materials.
There are many fine texts and corresponding activity books available for the first year of mathematics education courses for future K–8 teachers. See http://www.wou.edu/~burtonl/ for a list of curriculum resources for more advanced courses.

Recommendation: Use appropriate assessment techniques.
Standard assessment practices (homework and exams graded on procedure and success at achieving the correct answer) are not appropriate for mathematics education courses. In most of my mathematics education courses, *I assume my students can already solve the mathematical problems we are considering*. My goal is usually not to teach them new mathematical skills, but to help students thoroughly understand how known algorithms work. Some assessment techniques that I currently implement are:

- Requiring careful written explanations in the homework assignments. Students learn by explaining and illustrating how elementary mathematics works.
- Assigning book and teaching journal reports. This helps the students gain perspective on how the mathematics they are learning is connected to their future classrooms and introduces them to valuable resources.
- Asking students to do term projects involving the design of simple lesson plans and student activities for the elementary or middle school classroom. These projects relate the current course topics to the topics my students will eventually be teaching.
- Assigning small-group final presentations (games, lesson plans, etc.). This encourages cooperative work outside of the classroom as well as inside and helps students learn to work as an effective team.
- Using in-class, take-home, and oral exams. Students are asked to explain their procedures and to sketch out or show visual models that demonstrate their understanding of the topic.

I try to use assessment procedures that examine the students' knowledge at a variety of levels, introducing them to techniques they might use in their own classrooms and allowing for a variety of learning styles. Mathematics education students generally embrace these goals and feel much less intimidated by these evaluative procedures than by the usual kinds of mathematics assessment. This helps me create a positive learning atmosphere but permits effective evaluation of students' knowledge.

Recommendation: Expect motivated and successful students.
Students interested in careers as teachers are frequently the most enthusiastic and responsible of students. They will be training the next generation of students and deserve respect, support, and an opportunity for genuine mathematical advancement. Many K–8 teachers have not taken and will never take higher level mathematics (calculus and beyond). Some K–8 teachers, like many other people, feel that studying mathematics is cause for anxiety and that success in mathematics is beyond their reach. It is critically important that all future teachers, particularly those with misconceptions about their ability to succeed in basic mathematics, be allowed to develop their mathematical power in a friendly and helpful classroom.

Two Typical Students

Linda is energetic, extremely bright and has never taken any "pure" mathematics courses beyond high school. She plans to teach mathematics at the middle school level and is required to successfully complete eleven 3-quarter hour mathematics education courses. Linda turns in highly detailed work, which is full of insightful comments. Linda is often in my office, she wants to know everything and she is intensely intellectually curious. Her intellectual skills, her constant desire to learn and her drive to succeed ensure that she will be a dynamic middle school mathematics teacher.

Dianne has also never taken any "pure" mathematics courses beyond high school. She plans to teach at the fourth or fifth grade level and, with her focus in mathematics at the elementary school level, is taking eight 3-quarter hour mathematics education courses. Dianne is a quiet, somewhat shy student who frequently struggles with the mathematical concepts in my advanced mathematics education courses, especially at the beginning of the term. However, Dianne has a remarkable work ethic and an intense desire to learn. In several classes, Dianne submitted almost unbelievably outstanding final projects. Given the appropriate time and support, she was able to develop, on her own, detailed lesson plans and activities that elementary school children would love. Furthermore, these lessons demonstrated her deep grasp of the exact mathematical points emphasized in the course. Additionally her projects are some of the most creative term projects I have ever seen. Dianne creates her own success and will clearly be an asset to her future students.

These two students are particularly noteworthy, but in fact are surprisingly representative of mathematics education students at WOU. Their skills are built over time and flourish in an atmosphere emphasizing knowing and understanding elementary mathematics. In large part they are successful because they have had the opportunity to participate in a wide variety of mathematics education courses designed specifically for K–8 teachers. This is clear evidence that creating appropriate training opportunities for future teachers is an effective and worthwhile endeavor.

I believe it is no longer appropriate for mathematicians to consider themselves a separate community from mathematics educators. The need for quality education of our future teachers is just too great. Furthermore, entire departments should commit to, value and encourage participation in teacher education. Who will take the first steps in your department to enhance the mathematical education of teachers in your community? Will it be you?

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Laurie Burton (burtonl@wou.edu) is a Mathematics Education Specialist at Western Oregon University and will be co-directing a PREP workshop about K–8 teacher education this summer (http://www.wou.edu/~burtonl/).

NSF Beat
May 2003

By Sharon Cutler Ross

How do people learn mathematics? How do we best teach mathematics? The NSF's Research on Learning and Education (ROLE) program has made an initial round of awards for research into these and other questions about learning. The mathematics-related awards are summarized below. ROLE supports research related to human learning in the areas of brain research, behavioral, cognitive, affective, and social aspects of learning, and the learning of mathematics, science, engineering, and technology in informal or formal settings and in complex educational systems.

At Carnegie-Mellon (J. Anderson, PI), research is underway to improve tools for tracking how students solve mathematical problems. Both eye-movement scanning and fMRI imaging are being used to find improvements for a cognitive tutor that is being adapted for use in middle schools.

Improvement in the preparation of African-American students for algebra and higher mathematics is the goal of the ROLE project coordinated by Lesley College (F. Davis, PI). Schools in three urban settings form the research ground for identifying successful practices that increase the proportion of minority students who successfully complete algebra and enter college preparation tracks in high school.

An exploration of the interactions among diverse, connected classroom technologies is the prime activity of the project at University of Massachusetts-Dartmouth (J. Kaput, PI). Three areas of impact are considered – assessment, learning structures, and teaching. The goals are to inform iterative improvement of technological practices that support learning and of teacher development and support structures.

At Boston College (M. Martin, PI), rethinking and reconceptualizing the fifth international study of mathematics and science is supported by a ROLE award. Based on experience with previous assessments, such as TIMSS, frameworks for assessments in mathematics and science will be developed.

Ways to nurture and cultivate mathematical imagination are being investigated at TERC, Inc. (R. Nemirovsky, PI). A series of studies with teachers seeks to confirm that cultivating mathematical imagination is related to effective learning of mathematics.

The University of Colorado-Boulder (A. Perissini, PI) is continuing a study of two reform-based teacher education programs by following a group of pre-service teachers through their second year of teaching. Of particular interest is how teacher education impacts their learning and development as teachers.

The ROLE project at MIT (E. Spelke, PI) seeks to shed light on the teaching and learning of mathematics through a series of studies involving monkeys, infants, children, and adults. The goal is to investigate the sources of mathematical thinking throughout the developmental spectrum. ■

Sharon Cutler Ross is a member of the FOCUS and MAA Online editorial board. Her NSF Beat *column appears regularly in FOCUS. Past columns are archived on MAA Online.*