Professional Development for Mathematicians Teaching Pre-service Elementary Teachers in Alabama

Cristina Gomez, College of Education, University of Alabama
Wei Shen Hsia, Department of Mathematics, University of Alabama
Cecelia Laurie, Department of Mathematics, University of Alabama

Introduction

The term "professional development" has been used to described growth and change for teachers in schools but not so often for faculty at colleges and universities. The role of a facutly instructor in content courses for pre-service teachers is very similar to the role of a math teacher. We have found that the challenges and tensions are comparable. In particular, the use of new curriculum materials has created an opportunity for promoting faculty learning, supporting faculty practice and expanding faculty mathematical knowledge for teaching. In this paper we describe our experience with professional development of faculty at a mathematics department.

The RAND mathematics study panel (RAND, 2003) proposes a program of research and development in mathematics education to achieve mathematical proficiency for all students. The first strand of this program focuses on the mathematical knowledge required for teaching mathematics and the key resources needed to use that knowledge in teaching (p.15). Mathematicians like H. Bass (2005) recognize that this type of knowledge is not known by many mathematically trained professionals, such as, research mathematicians (p. 429). For most elementary teachers, their mathematical knowledge comes from the content courses taken in college, taught by mathematicians who are not always familiar with the specialized mathematical knowledge required for teaching. This gap shows the clear need for collaboration between mathematicians and mathematics educators to explore deeply the meaning, development and use of this knowledge in teacher preparation.

Our work at the University of Alabama during the last three years has been a collaboration between the Department of Mathematics (two mathematicians) and the Teacher Education Program in the College of Education (one mathematics educator). It has focused on a professional development program for faculty at the mathematics department to explore these issues and to support the faculty in the process of understanding mathematical knowledge for teaching. This effort aligns with one of the goals of the MAA-Preparing Mathematicians to Educate Teachers program: "Support mathematicians to become more effective in helping future K-12 teachers develop a deeper understanding of the mathematical ideas that arise in K-12 teaching practice and pedagogical strategies appropriate for these ideas."

Courses for pre-service elementary teachers

We have followed a cycle of knowledge production and improvement of practice (RAND, 2003, p. 6) at the level of our institution. We began with the study of the basic problems of teaching content courses for pre-service elementary teachers and their learning (or lack of) when taking the traditional "grab-bag" courses. When we started our work, there was only one such math content "grab-bag" course specifically for elementary school mathematics. Based on results from research available and recommendations of national organizations (such as NCTM and the CBMS Mathematical Education of Teachers report (2001)), we developed curriculum materials for three mathematics courses designed specifically for pre-service elementary teachers. The framework for the development of these courses is based on two big ideas--

profound understanding of fundamental mathematics as described by Ma (1999) and mathematical knowledge for teaching as described by Ball & Bass (2000).

We first give a brief description of these two ideas and then give an example of how they are incorporated in our curriculum with regard to multiplication and division of whole numbers. Ma's definition of *profound understanding* of fundamental mathematics includes four components (1999) – (1) Connectedness: a teacher with profound understanding has a general intention to make connections among mathematical concepts and procedures (2) Multiple Perspectives: those who have achieved profound understanding appreciate and can provide mathematical explanations for different facets of an idea and various approaches to a solution, as well as their advantages and disadvantages (3) Basic Ideas: teachers with profound understanding revisit and reinforce 'simple but powerful basic concepts and principles of mathematics' (4) Longitudinal Coherence: teachers with profound understanding are ready at any time to exploit an opportunity to review crucial concepts that students have studied previously and are able to take opportunities to lay the proper foundation for what students will study later. In order to determine *mathematical knowledge for teaching*, i.e. pedagogically useful mathematical understanding, Ball and Bass (2000) describe a mathematical analysis of core activities of mathematics teaching. Core activities of teachers include such things as "figuring out what students know; choosing and managing representations of mathematical ideas; appraising, selecting, and modifying textbooks; deciding among alternative courses of action; and steering a productive discussion."

As an example of how profound understanding and mathematical content knowledge for teaching are addressed in our curriculum, we describe the treatment of multiplication and division of whole numbers. We begin with an activity consisting of several word problems that students solve by direct modeling using counters. Beginning with word problems provides contexts upon which meaning can be built. Class discussion of the differences and similarities in the modeling strategies leads to abstracting the basic structure of the operations (multiplication and division): problems using multiplication or division involve forming a certain number of groups of objects of equal size from a total number of objects; the differences involve recognizing which quantities (total number of objects, number of objects in a group, or the number of groups) are known and which are unknown. This structure is a "basic idea" that is revisited and reinforced. In the process of leading the discussion, the instructor models the core activity of figuring out what students know and building on this knowledge. The next activity has students analyzing the structure of word problems as well as writing their own word problems, laying the foundation for the core activity of selecting problems that will develop and assess understanding. Students then engage in activities that involve varied strategies and representations for solving multi-digit multiplication and division problems. These include direct modeling, using basic number facts along with place-value understanding and number sense, and using the area model for multiplication to solve problems as well as develop properties of the operations. Pre-service teachers develop their own strategies as well as analyze children's ways of thinking (correct ways as well as ones involving misconceptions). The emphasis is on explanations of the strategies in terms of not only number sense but also in terms of the meanings of the operations (a continued focus on "basic ideas"), laying the foundation for the core activity of choosing and managing representations of mathematical ideas. By working with and explaining multiple perspectives, pre-service teachers move toward profound understanding. Final activities engage the pre-service teachers in understanding standard algorithms, why they work and how they relate to other strategies. A teacher with "profound understanding" makes connections among mathematical concepts and procedures. Throughout the activities, the

instructor models classroom discourse – steering a productive discussion and building on student understandings (and misunderstandings) that arise during the discussion.

All the topics in the courses are treated in a similar way. The goal is to help the pre-service teachers develop their knowledge for teaching and to get some practice in the core activities of teaching.

Engaging faculty in teacher preparation courses

Developing these courses has been and continues to be an intensive professional development process for the two mathematicians involved. It requires reading research literature and discussing the implications with each other and the math educator on our team, trying activities culled from varied sources, discussing how the activities align with the research, reflecting on our implementation of the activities – what worked and didn't work with our students, and continually revising the materials and practice. The collaboration with the math educator was crucial to our efforts. We became convinced of the need for interweaving pedagogy and content in these courses. We also recognized that this not only required specialized knowledge that most mathematicians are not aware of (as noted by Bass 2005), but also required a different mindset and ways of interacting with students than most of us were accustomed to.

As a logical next step, we saw the need to involve other mathematicians in the process of understanding this specialized knowledge for teaching elementary mathematics. It was important to build support for our efforts within the mathematics department as well as to encourage more mathematics faculty to become directly involved in teaching these courses. To achieve these goals we planned and implemented workshops for faculty. We held two one-day workshops sponsored by a PMET mini-grant. Both workshops were organized with the same structure. Participants included mathematics faculty (from the University as well as from local community colleges and other four-year colleges), mathematics education faculty, and elementary school teachers. The topics and the relevant literature were presented in the morning, followed by a demonstration class with volunteer students from the teacher education program and a discussion of the lesson. In the afternoon the discussion was more open, having more input from participants and creating an opportunity for school teachers to share their experiences.

The first workshop was held in Spring 2004. The main topic for this workshop was an overview of the recommendations from the CBMS-MET report (2001) and some of the leading research in the area of content knowledge for teaching. We engaged participants in an activity designed to raise awareness of the depth of mathematics involved in elementary school mathematics. We also discussed the role of the teacher in a classroom that promotes understanding and the demonstration class showed how this role could be modeled in a teacher preparation course.

The second workshop was held in Fall 2004. In this case the main topic was the use of technology in the preparation of prospective teachers. The two software programs used in the other two courses for teachers were presented with examples of how we use them in the courses. Geometer's Sketchpad and Fathom are used in the Geometry and the Data Analysis courses. We discussed the technology standard from the Principles and Standards of School Mathematics (NCTM, 2000) and research related to the use of technology in math courses. Again, the demonstration class showed how the use of Geometer's Sketchpad supports student's development of mental images of geometric shapes. The afternoon session included activities using physical manipulatives as tools for learning.

Both workshops were very well attended and received by the participants. Feedback was positive and indicated that we had made progress toward communicating the importance of

designing courses for teachers that deepen their understanding of the mathematics that they will teach. Participants particularly appreciated the opportunity to share perspectives brought by mathematicians, education faculty and elementary school teachers. The fact that there was good participation for these all-day workshops, held on Saturdays, indicated interest on the part of the mathematical community in teacher preparation. Ongoing workshops to continue the dialogue would create a supportive environment for strengthening our role in the mathematical education of teachers.

As result of these workshops, three additional faculty members were recruited to teach the courses. We currently have five (5) tenured mathematics faculty teaching courses for pre-service elementary teachers. As we engage additional faculty in teaching these courses, we mentor them. Before teaching the course, the faculty member observes several classes being taught by one of the developers. During the semester that the faculty member teaches a section of the course, one of the developers is teaching another section and coordinates closely with and mentors the faculty member. This process also provides us with valuable feedback in refining the course materials as well as information on how better to help faculty appreciate the interweaving of pedagogy and content.

Finally, in response to a need of the community, we organized workshops for mathematicians at other local institutions, who were interested in the same issues. A second PMET mini-grant supported a 3-day intensive workshop in Summer 2005 for 7 participants from 6 different colleges (some community colleges, some four-year colleges, one math faculty member from our institution). The workshop leaders included an experienced elementary school teacher. The workshop began with an overview of developing profound understanding and mathematical content knowledge for teaching. The core of the workshop activities focused on a few basic concepts, modeling classroom activities that promoted understanding and knowledge for teaching. For example, one set of activities engaged the participants in the curriculum lessons designed for multiplication and division of whole numbers as described above. The participants played the role of students in the class as the workshop leaders 'conducted' the class using the inquiry-based materials. During the intervening time between the first two days of the workshop (corresponding to first summer session) and the final day, participants either used the materials that we provided in teaching a course at his or her institution during first summer term or observed several classes of the course being taught at our institution. The final day of the workshop included reflection on the observations or use of the materials with a focus on mathematical knowledge for teaching, understanding student thinking, and core concepts. All participants expressed that they gained ideas for enriching their current courses and many expressed the desire for more opportunities to engage with these ideas.

Conclusion

Our experiences show that ongoing professional development of faculty teaching mathematics content courses for pre-service elementary teachers is a clear need for many mathematics departments. Just as with school teachers, college faculty need support and training in how to use effectively new curriculum materials, how to anticipate and interpret students' responses, how to identify important ideas in school mathematics, and how to make pedagogical decisions. This work should be done in collaboration with mathematics educators in colleges of education in order to share expertise and provide a coherent, integrated mathematical education of pre-service teachers.

References

Ball, D. L. and Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.), Multiple perspectives on the teaching and learning of mathematics (pp. 83-104). Westport, CT: Ablex

Bass, Hyman (2005). Mathematics, mathematicians, and mathematics education. *Bulletin of the American Mathematical Society*, Volume 43, No. 4, 417-430

Conference Board of the Mathematical Sciences (2001). *The Mathematical Education of Teachers.* Mathematical Association of America, in cooperation with the American Mathematical Society, Providence, Rhode Island

Ma, L. (1999). *Knowing and teaching elementary mathematics*. Mahwah, NJ: Erlbaum.

RAND Mathematics Study Panel (2003), *Mathematical Proficiency for All Students*. Science and Technology Policy Institute, RAND Education