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Mathematics Teacher Education: At a Crossroad

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The work of mathematics teacher educators takes many forms – curriculum development, research, professional development, policy making, assessment, and evaluation. This paper uses the Interventions entry point from the RAND Study Cycle of Knowledge Production and the Improvement of Practice to consider the work of mathematics teacher educators related to preservice teacher education, professional development, and curriculum.

When we find ourselves at a crossroad, our instinct is to aim in the direction we want to go to get to the place we want to be. This thinking implies a clear choice of the right direction. Yet, for many reasons, not the least of which is the rapidly changing world in which we live, there is no such clear choice for mathematics teacher educators. We have reached a place in our profession where we recognize that the only defensible directional goal is to commit ourselves to successive approximations toward the nirvana where every teacher of mathematics has the right stuff and a fire in his or her belly to reach every child. Consequently, mathematics teacher educators need to build a profession that thrives on the challenge of examining, with curiosity, commitment, and vigor, the hard problems inherent in the teaching and learning of mathematics and the preparation and lifelong support of K-12 teachers. No organization is better positioned than the Association of Mathematics Teacher Educators (AMTE) to lead the development of such a profession.

Mathematics teacher educators work in many different ways — curriculum development, research, professional development, policy, and assessment and evaluation, among others. Wherever our work is situated, it is the contribution we make to the mathematical learning of K-12 teachers and their students that ultimately matters. In this paper, we focus on three areas of work in which AMTE members engage and suggest some promising future directions. To begin, we use a schematic from the RAND Mathematics Study Panel as an organizer for situating the areas of work.

The RAND Study Panel Report

The RAND Mathematics Study Panel report, *Mathematical Proficiency for All Students: Toward a Strategic Research and Development Program in Mathematics Education* (RAND Mathematics Study Panel, 2003), presents a provocative cycle of research, development, improved knowledge and practice, and evaluation. The cycle leads to new research and new development with the goal of producing new knowledge and understandings and improving practice.

As Figure 1 makes clear, one can enter this cycle of improvement at different places and professionals in mathematics teacher education do so. In this paper we choose the *Interventions* entry point with sections devoted to work in preservice teacher education, professional development, and curriculum.

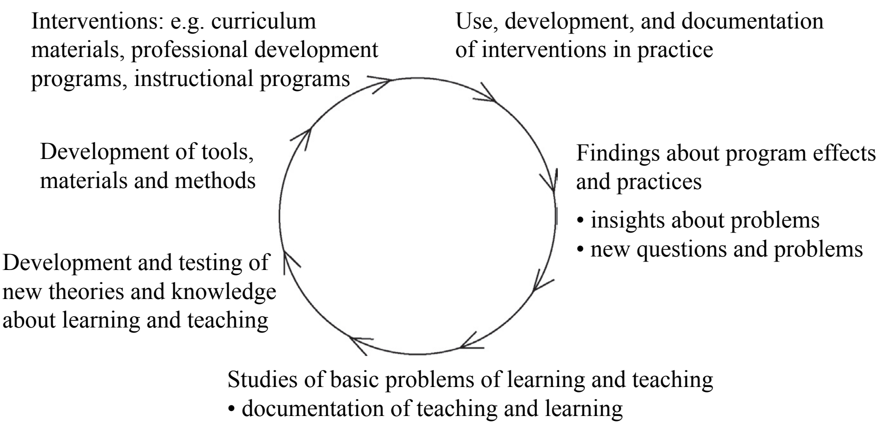

Figure 1. Cycle of Knowledge Production and the Improvement of Practice (Reprinted from *Mathematical Proficiency for All Students: Toward a Strategic Research and Development Program in Mathematics Education* with permission of the RAND Corporation ©2003. All rights reserved.)

The Preservice Education of Teachers

As a result of experience and research, mathematics teacher educators know that K-12 mathematics teaching involves a myriad of complexities beyond the organization of daily lesson plans, the development of test items, and classroom discipline. Although debates on what courses should be taught for preservice teachers, what the goals for these courses should be, and who should teach them remain, it is the responsibility of mathematics teacher educators to make suggestions and help make decisions about the directions to take. Whatever decisions are made, preservice teachers should exit their teacher preparation programs with experiences that have deepened their mathematical knowledge and helped them reflect on and defend or amend their own beliefs about the role of a mathematics teacher, mathematics as a discipline of study, and how mathematics can be effectively taught and learned.

The NCTM *Principles and Standards for School Mathematics* (2000) recommend that the different content strands of the mathematics curriculum be developed K-12: Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability. These content strands, along with the process strands of communication, reasoning and proof, problem solving, connections, and representation, can serve as a guide in the development of preservice teacher knowledge. The *Mathematical Education of Teachers* (MET) publication (Conference Board of the Mathematical Sciences, 2001) was created to stimulate improvement in programs for prospective teachers and offers recommendations on the nature of coursework for preservice K-12 teachers. MET includes classroom vignettes and examples to portray ways that teachers use their mathematical knowledge for teaching. The depth and breadth of mathematical knowledge described in the MET document includes the characteristics of understanding articulated by Liping Ma as a *profound understanding of fundamental mathematics content* (Ma, 1999). Ma defines profound understanding of fundamental mathematics as “an understanding of the terrain of fundamental mathematics that is deep, broad and thorough” (Ma, p.120).

In addition to the mathematical content offered in coursework, courses and field experiences can offer preservice teachers opportunities to reflect on the role of a mathematics teacher in helping students learn mathematics with deep, broad, and thorough understanding. Many of the papers in this monograph offer suggestions on engaging preservice teachers in reflection on the teaching of others and on their own teaching. Some suggestions include using alternative assessments to challenge mathematical beliefs (Coffey) and using audio- or videotape as a means of analyzing one's teaching (Taylor & O'Donnell). Using clinical interviews of children to assess teacher candidates in mathematics methods coursework can also challenge preservice teachers to examine their beliefs (Moyer-Packenham). Engaging preservice teachers in courses that "problematize familiar mathematical concepts" (Van Zoest, this volume, p. 121), require them to teach important concepts to a small group of middle-grades students, and then reflect on the experience with others can prompt an examination of beliefs about students' learning and what is important for students to know and be able to do.

Other ways to foster reflection on the role of a mathematics teacher are through Japanese Lesson study (see Bass, Usiskin, & Burrill, 2002) and videos of teachers in the field. Magdalene Lampert's and Deborah Ball's work around the video data they collected as part of the Mathematics And Teaching through Hypermedia (MATH) project at Michigan State University offers teacher educators a multimedia approach to mathematics teacher education (see Lampert and Ball, 1998). These examples of tools can give preservice teachers an opportunity to look into a classroom and discuss issues involving student and teacher knowledge, discourse, and decision-making.

Professional Development

Professional development activities are as old as schooling. However, the past two decades represent a time of particular focus in the U.S. on understanding and developing professional development strategies that have lasting payoff for teachers. In the papers in this monograph you will encounter a number of streams of work on professional development. We highlight a few promising directions in this paper by giving examples of professional development activities that focus on curriculum inquiry and students' mathematical work.

Curriculum Inquiry

Teachers, through their education and experience in the classroom, learn the skills and facts of the subject that they teach. There is often little in curriculum materials or the assessments for which teachers are held accountable that pushes toward conceptual rather than instrumental learning (Skemp, 1978). In our experience, it is extremely difficult for teachers to conceive of, plan for, and carry out teaching that has the goal of helping students make sense of ideas, connecting them to what they already know, and pushing further to see where they might lead, etc., without the support of good curriculum materials and opportunities for interaction with other teachers and professionals around that curriculum.

Curriculum materials can provoke dissatisfaction with limited learning opportunities for students. They can raise the possibility of engaging students with subject matter content in challenging ways. However, unless materials and professional development activities around the materials also provide opportunities for teachers to consider instructional strategies that support the goal of deeply understanding the concepts and related skills and procedures embedded in the materials, the curriculum does not reach its potential. As teachers enact curriculum they may or may not actually teach what the curriculum developers intend. So what can help teachers become classroom partners in curriculum development? One part of the answer is professional development. In 1999 and 2000, Janine Remillard published results from an interesting study and follow-up in which she examined what teachers learn from the enactment of reform-oriented text materials in their classrooms. In the two cases she developed, her study teachers learned mathematics and considered classroom instruction, but with very different levels of engagement and results. One indicator of these differences is shown in the following table (Remillard, 1999).

From her study of these two teachers, Remillard built a model to portray the interaction of her two subjects' arenas of influence

Table 1. Teachers' Patterns in Reading the Textbook During Task Selection

	Number of lessons observed	Number of lessons involving text	Number of lessons including item from… Student page	Margin of student page in teacher's guide	Supplemental pages of teachers' guide
Jackie	14	4	3	4	4
Catherine	15	14	14	14	1

(From J. T. Remillard (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry*, *29*(3), 315-342. Reprinted with permission of Blackwell Publishing.)

while implementing the curriculum: Jackie and Catherine's beliefs about learning; their views of mathematics; and their interaction with the materials. Her model raises the issue of what professional development opportunities help teachers focus on the enactment of curriculum materials.

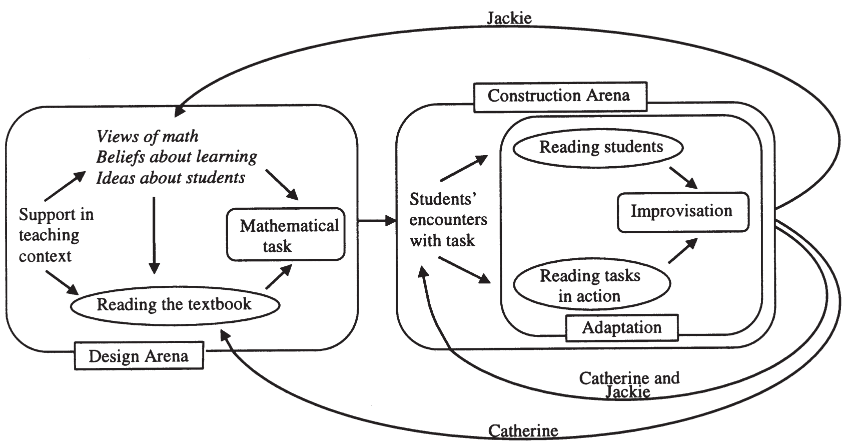

Figure 2. Model of the design and construction arenas in Catherine's and Jackie's teaching, illustrating the relationship between each arena and the influential factors within each
(From J. T. Remillard (1999). Curriculum materials in mathematics education reform: A framework for examining teachers' curriculum development. *Curriculum Inquiry*, 29(3), 315-342. Reprinted with permission of Blackwell Publishing.)

Remillard is a Co-PI of *Mathematics in America's Cities,* the newly funded Center for Teaching and Learning involving Rutgers, City

College of New York (CUNY), and the University of Pennsylvania. The work of this center will be of interest to AMTE members as the Center's goal is to produce knowledge that can inform mathematics teaching practices in urban settings. All the districts involved have adopted new reform-oriented mathematics curriculum materials. Remillard's previous research suggests that professional development focused on the work of teachers in their classrooms as they implement new curricula can be successful in engaging teachers more deeply in examining their practice.

In the Classroom Coaching Study conducted from 1985 to 1987, our research and development group at Michigan State University studied the effects of classroom coaching on teachers' practice and their ability to adapt the teaching strategies they were learning from interaction with coaching and the Middle Grades Mathematics Materials (MGMP) (Fitzgerald, Lappan, Phillips, Shroyer, & Winter, 1986) to their traditional text. The 12 teachers in the study were assigned to three treatment groups. Four participated only in the intensive whole group professional development activities over the two years; four, in addition, had a classroom coach at three extended time periods over each year while teaching an MGMP unit; and four, in addition to classroom coaching, were coached to work with another teacher in his or her building in the second year (Fitzgerald, Lappan, Phillips, & Winter, NSF Final Report, NSF/MDR–83-18218). One goal of our work was to direct teacher's attention from student behavior to student cognition through our professional development and coaching.

Through analysis of the documentation, which included field notes from classroom observers, periodic surveys of teachers' beliefs about teaching and student learning, assessment of teachers' mathematical knowledge, and periodic teacher interviews, we found that coaching was effective in helping teachers improve their teaching and in shifting their primary focus to student cognition. However, we were surprised by our observations when one of the coached teachers and one of the un-coached teachers each had a student teacher. The un-coached teacher had no processes or effective language through which to analyze or plan lessons. She was a good teacher, but her classroom strategies were instinctive rather than the result of conversation and reflection. The coached teacher was highly effective in helping her student teacher. Through the previous year of periodic intensive analysis and planning of mathematics lessons together, she and her coach had developed a language with which to discuss classroom practices. This language helped her to be an effective coach of others. This mid-80's work supports the current push toward developing communities of practice within which to support teacher learning.

Student's Mathematical Work

In 2002, the Victoria Department of Education and Training, the Catholic Education Office (Melbourne), and the Independent Schools in Victoria issued a comprehensive report on the Early Numeracy Research Project (ENRP), currently available on CD-ROM. This report outlines the results of a large-scale study, directed by Doug M. Clarke (Clarke et al., 2002). As stated in the report (p. 11),

> The stated aims of the Early Numeracy Research Project were the following:
>
> - to assist schools to implement the key design elements as part of the school's mathematics program;
> - to challenge teachers to explore their beliefs and understandings about how children develop their understanding of mathematics, and how this can be supported through the teaching program; and
> - to evaluate the effect of the key design elements and the professional development program on student numeracy outcomes.

The study team developed a framework of "growth points" in young children's understanding of mathematics across a range of mathematical domains. Once the mathematical analyses were done and the framework was developed, the rest of the development work and the professional development activities were driven by progress on children's attainment of these "growth points."

Throughout the trial and reference schools at the three grades studied, 34,398 students were interviewed one-on-one by their teacher.

The sheer scope and magnitude of the study is stunning as is the growth of the students in the trial sites over all mathematics domains tested. The growth of the trial teachers in their teaching effectiveness and content knowledge was equally impressive. The teachers' views changed from expecting the researchers to give them a recipe for what they should be doing to embracing the notion of creating *rich ingredients* for their practice that they combined to meet the needs of individual children.

Two of the key recommendations from this study show the intertwined nature of mathematical goals in curriculum inquiry and examining student work.

Recommendation 6:

> It is recommended that professional development provided to preservice and inservice teachers in early mathematics teaching and learning give particular focus to the ENRP Growth Points as a basis for guiding teachers' thinking and for assessment and planning.

Recommendation 7:

> It is recommended that the summary of the practices of effective mathematics teachers that emerged from the ENRP case studies, and the documented changed practices of trial school teachers form the basis of professional development on mathematics teaching practices. (p. 28)

The report makes clear that professional development that engages teachers in studying the progress of their students on well articulated goals and indicators of learning helps teachers improve their classroom practices and adds to their understanding and command of the mathematics they need for teaching. What we need now are a series of projects that systematically extend such analytic work and study to higher grades in K-12 mathematics education.

Research over the past decade points to the need for teachers to confront what their students know and do not know. This implies that students' work, whether it be test performance or regular class activity, can be a powerful tool for causing the dissonance needed to capture teachers' attention and curiosity. Current professional development studies in the U.S. share a common core of ideas about effective professional development:

- The classroom should be used as a laboratory for exploration of teaching and learning so that professional development interacts with teachers' regular teaching responsibilities.
- Teachers should be equal partners in improving mathematics teaching and learning.
- Video cases, written cases, and other artifacts of classroom practice, such as student work and assessments, can be used to promote deep analysis of teaching practices and of mathematics for teaching.
- Good curriculum materials chosen by the school can be an effective focus for professional development.

Curriculum

Jerome Bruner, in the 1990 Karplus address given at the annual National Science Teachers Association meeting, paid a tribute to Karplus (Bruner, 1992):

> What he knew was that science is not something that exists out there in nature, but that it is a tool in the mind of the knower—teacher and student alike. (p. 5)

Bruner goes on to say

> Getting to know something is an adventure in how to account for a great many things that you encounter in as simple and elegant a way as possible. And there are lots of ways of getting to that point, lots of different ways. And you don't really ever get there unless you do it, as a learner, on your own terms. All you can do for a learner enroute to their forming a view of their own view is to aid and abet them on their own voyage. (p. 5)

Although these remarks were made about science, they resonate with the reformulation of curriculum goals for mathematics K-12 worldwide.

For over three decades, a variety of national and international studies of student achievement have suggested that American practices in mathematics education are not yielding the kind of learning that is both desirable and possible (e.g., Second International Mathematics Study, National Assessment of Educational Progress, Third International Mathematics and Science Study, Programme for International Student Assessment). Comparing curricula and instructional practices in U. S. schools with those in countries with high student achievement revealed intriguing ideas about ways to improve our own results (e.g., Hiebert & Stigler, 2000; McKnight, et al.,1987; McKnight & Schmidt, 1998; Stigler, Lee, & Stevenson, 1990). Studies of mathematics curricula and teaching in Asian and European countries that are our intellectual and economic competitors showed that, in general,

- Our curricula do not challenge students to learn important topics in depth (Schmidt et al., 1999);
- Our teaching traditions encourage students to acquire routine procedural skills through a passive classroom routine of listening and practicing;
- Our assessment of student knowledge emphasizes multiple choice and short answer responses to low-level tasks. (McKnight et al., 1987).

Against this backdrop, the recommendations in the National Council of Teachers of Mathematics *Standards* documents (1989, 1991, 1995) called for major changes in traditional patterns of curriculum, teaching, and assessment in school mathematics. These ideas were refined and enhanced in the NCTM *Principles and Standards* in 2000. However, to make a difference, the vision of curriculum articulated in the *Standards* volumes as well as teaching, learning, and assessment around that curriculum has to be translated into effective and practical models.

In a paper presented at an AAAS symposium on curriculum development, Phillips, Lappan, Fey, and Friel (2001) articulated the following principles for curriculum materials that are emerging out of current curriculum development work.

- An effective curriculum has coherence—it builds and connects from investigation to investigation, unit to unit, and grade to grade.

- The key mathematics ideas around which the curriculum will be built are identified.
- Each key idea is related to a number of smaller concepts, skills, or procedures that are identified, elaborated, exemplified, and connected.
- Mathematics tasks that will form the work of students both inside and outside of class are the primary vehicle for students' engagement with the concepts to be learned.
- Posing mathematics tasks in context provides support for both making sense of the ideas and for processing them so that they can be recalled.
- Ideas are explored in sufficient depth to allow students to make sense of them.

These principles are more apparent in the new generation of mathematics curriculum materials that have emerged in the past decade. They represent a way of monitoring the development of new curricula as well as analyzing existing curriculum materials. They also suggest that the kind of curriculum development that has begun over the past decade represents demanding scholarship that needs to be recognized and rewarded in higher education faculty reviews. The work of figuring out how to assess the scholarship of curriculum development is a challenge that we as a field need to undertake.

The National Science Foundation, in recognition of the importance of curriculum in improving mathematics education, has recently funded two centers to focus on curriculum research: the Center for Curriculum Materials in Science (CCMS); and the Center for the Study of Mathematics Curriculum (CSMC). A sample of the kinds of questions that the mathematics curriculum center (Reys, Lappan, & Hirsch, 2003) will pursue follows.

<u>Curriculum Design</u>

- What principles for the design of curriculum materials can be drawn from contemporary research and theory on learning?
- How can mathematics curriculum materials be designed to serve the learning needs of students from diverse cultural

backgrounds and help to reduce the achievement gap among various populations of students?

- How might mathematics curriculum materials be designed to capitalize on continued advances in computing technologies?
- How can the knowledge gained from experienced mathematics curriculum developers be used to inform and prepare future writers of curriculum materials?

Curriculum Implementation

- What are the key factors involved in adopting and successfully implementing high quality mathematics curriculum materials?
- To what extent and under what conditions do mathematics curriculum investigation and implementation serve as vehicles for professional development and teacher learning?
- To what extent and under what conditions can mathematics curriculum materials promote teacher learning and effective teaching?

Curriculum Evaluation

- What are some of the critical features of mathematics curriculum materials that support student learning?
- What is the relationship among local or state curriculum standards, curriculum materials, and high stakes assessments?
- What evaluation tools are most effective when studying mathematics curriculum? What information do they yield for various purposes? What are their limitations?
- In what ways are evaluation data used to make school-based curriculum decisions?

CSMC has as an ongoing goal to develop tools and to inform and stimulate the field to engage in the study of curriculum and curriculum development as a vehicle for student and teacher learning. With systematic attention to the problem, perhaps in five to ten years we will be in a different place in our understanding of scholarship around the study of curriculum and be able to support young professionals with such interests through the higher education reviews that are a part of monitoring the quality of our work.

Summary

The *Cycle of Knowledge Production and the Improvement of Practice,* articulated by the RAND Study Panel chaired by Deborah Ball and illustrated in Figure 1, can be an important tool in examining where the field is and what AMTE as an organization can promote to improve the teaching and learning of mathematics. The Cycle makes clear the need for intensive study of current interventions with the goal of understanding program effects and determining new questions such interventions raise. The Cycle also promotes the need for mathematics teacher educators to engage in serious, long-term work to build theories that can guide new stages or iterations of both development and research programs. Such theory building is improved by “trips” through the stages of the cycle. Theories that are well articulated and shared with other professionals can also guide the development of research instruments, analytic strategies, and coding schemes for making sense of data.

We recognize that there is a human capacity problem associated with the enactment of such a cycle of improvement. To make a research-based cycle work, there have to be sufficient numbers of well-educated professionals to carry out the work. AMTE can play a major role in helping to develop young professionals to engage in systematic, articulated work to improve mathematics teaching and learning. The National Science Foundation, through its Centers for Teaching and Learning (CLT) program, has human capacity building as a primary goal. We would encourage AMTE to encourage promising teachers and strong undergraduate and master’s students to take advantage of the support for doctoral work at one of the CLT Centers.

The *Cycle of Knowledge Production and the Improvement of Practice* will not in and of itself automatically advance the field. However, it can help us build a more coherent knowledge base on which to educate current and future teachers of mathematics.

Whether one's work is situated in a department of teacher education, a department of mathematics, a school district or state office, or somewhere else in the system, the Cycle can help us articulate the primary focus of our work and see ourselves as a part of a more connected enterprise dedicated to improving the teaching and learning of mathematics in this country.

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