Prospective and Practicing Teacher Professional Development with Standards

Akihiko Takahashi, Ph.D., Depaul University

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Introduction

It is obvious that teachers cannot teach mathematics beyond their knowledge (National Mathematics Advisory Panel, 2008) but even having this knowledge is not nearly enough to teach mathematics effectively. In order to promote high quality mathematics education for all, ministers of the Asia-Pacific Economic Cooperation (APEC) released a strategic action plan and recommendations for priorities of mathematics and science education[1]. The recommendations recognize the needs of teachers with strong knowledge and expertise in providing high-quality learning opportunities for their students.

In order to promote high quality mathematics education for all, it is critical for universities and school systems to provide both prospective and practicing teachers with opportunities not only to increase their knowledge for teaching mathematics, but also to develop the expertise for teaching mathematics.

In this paper, I discuss the roles of universities and school systems in providing high-quality learning experiences for prospective and practicing teachers -- establishing a strong foundation for teaching mathematics for future generations.

Issues in teaching mathematics

One of the major challenges in mathematics education is the reliable implementation of insights gained from research into the classroom. Despite the fact that researchers have developed great ideas and resources for teaching mathematics, Stigler & Hiebert (2009) argue that the substantive nature of what happens in classrooms has not been changed much.

One of the reasons for this phenomenon may be the lack of the opportunities for prospective and practicing teachers to develop expertise in using ideas from research in their teaching practice. As Polya begins his famous book, *How to Solve It* (1945), helping students to learn mathematics demands time, practice, devotion, and sound principles. Unfortunately many school systems do not have adequate supporting structures for their teachers to develop knowledge and expertise for supporting their students in learning mathematics. As a result, many educators are essentially teaching the same way they were taught in school (Conference Board of the Mathematical Sciences Washington DC. National Advisory Committee on Mathematical Education.[BBB12494], 1975).

In order to bring ideas from research into the classroom, thereby improving teaching and learning mathematics, providing teacher preparation programs for prospective teachers is not enough. Continuous professional development for practicing teachers is also important. Therefore, universities and school systems should be the place for supporting both prospective

[1] http://hrd.apecwiki.org/index.php/4th_APEC_Education_Ministerial_Meeting_%28AEMM%29_in_Lima_Peru

and practicing teachers in developing knowledge and expertise for their students to learn mathematics.

Resources to support developing knowledge and expertise required for teaching mathematics

Once standards are developed, researchers, curriculum coordinators, and textbook authors and publishers carefully align the curriculum and design materials for implementing the standards. Although it is essential to have a set of good curriculum materials, including textbooks, manipulatives, technological tools and workbooks, developing resources to help teachers develop deeper understandings of the standards and the curriculum materials is also important. When developing such resources for prospective and practicing teachers, it is critical to recognize what knowledge and expertise is necessary for teachers to implement the standards into every day classrooms.

An idea shared among Japanese mathematics educators gives us a framework to examine in terms of teachers' knowledge and expertise for teaching mathematics.

Although most teachers use textbooks as their primary instructional materials (Shimahara & Sakai, 1995; Sugiyama, 2008), Japanese teachers and educators recognize that there are different ways to use textbooks and these ways are significant for student learning. The educators emphasize a distinction between "teaching the textbook" and "teaching mathematics using the textbook." To teach the textbook, teachers need little knowledge about mathematics; they can simply tell students what is in the textbook. However, to teach mathematics *using* the textbook, teachers need to possess a much deeper understanding of mathematics and how students learn mathematics.

In order to provide better learning experiences for students, all teachers should be able to teach mathematics using the textbook effectively. "Teaching the textbook" is not enough. What knowledge and expertise are Japanese teachers expected to develop in order to use the textbook effectively? When and how do Japanese prospective teachers and novice teachers acquire that knowledge and expertise?

Three levels of teaching

Knowing the content in textbooks is the most important foundation in order to be a teacher, however it is not enough to be an effective teacher. Japanese mathematics educators and teachers understand that there exist several levels of teaching between "teaching the textbook" and "teaching mathematics by using the textbook". Japanese mathematics educators typically characterize teacher expertise according to three levels (Sugiyama 2008):

- Level 1: Teachers can tell students important basic ideas of mathematics such as facts, concepts, and procedures.
- Level 2: Teachers can explain the meanings of and reasons behind the important basic ideas of mathematics in order for students to understand them.
- Level 3: Teachers can provide students opportunities to understand these basic ideas, and support their learning so that the students become independent learners.

Although it is essential for teachers to be able to tell students important facts, a teacher at Level 1 is not yet considered a professional. Sugiyama (2008) writes that during the early 20th century, which is considered an early stage of the Japanese public education system, most elementary school teachers were at Level 1. They told their students the facts and expected them to memorize those facts through practice. Textbooks at that time were designed to support this form of instruction.

Level 2 teachers have to know mathematics beyond what is used in everyday life or what is required to solve problems in elementary school textbooks. For example, it is enough for a Level 1 teacher to know that, when dividing fractions, a quotient can be found by multiplying the reciprocal of a fraction. However, Level 2 teachers should be able to explain how multiplying by the reciprocal of a fraction produces the quotient. This type of knowledge is important for helping students understand mathematics. Japanese mathematics educators consider that a teacher at Level 2 can be a considered a professional.

Although Level 2 teachers are considered professionals, Japanese mathematics educators believe that all teachers of mathematics should be at Level 3. This is because Level 2 teachers cannot provide adequate opportunities for students to develop proficiency with understanding.

The differences between Level 3 teachers and other levels can be understood by looking at how they might use a problem in a textbook. A Level 1 teacher would present the problem and show the steps for solving it. A Level 2 teacher would show the steps and explain why those steps are correct and useful. A Level 3 teacher, in contrast, would present students with the same problem, providing structure and guiding the conversation, so that students arrive at a new understanding as a result of their own efforts in solving it. The philosophy behind Level 3 teaching is that students should have reasonable independent work, such as problem solving, in order to develop knowledge, understanding, and skill of mathematics (Lewis & Tsuchida, 1998; J. Stigler & Hiebert, 1999; Akihiko Takahashi & Yoshida, 2004; Yoshida, 1999).

Therein lies the distinction between “teaching the textbook” and “teaching mathematics using the textbook.” Since Level 3 teaching clearly requires greater knowledge and expertise beyond knowing and being able to use mathematics in practical situations, the following question still remains: What professional development programs do teachers need to develop such knowledge and expertise?

Two major types of professional development

When designing professional development programs for prospective and practicing teachers, it is useful to recognize that the professional development programs might be categorized into two types: Phase 1 and Phase 2.

Phase 1 professional development focuses on developing knowledge for teaching mathematics: content knowledge of mathematics, pedagogical content knowledge for teaching mathematics, curricular knowledge for designing lessons, and general pedagogical knowledge (Fernandez, Chokshi, Cannon, & Yoshida, 2001; Lewis, 2000; Lewis & Tsuchida, 1998; J. Stigler & Hiebert, 1999; A. Takahashi, 2000; Yoshida, 1999). In order for teachers to develop such knowledge, this type of professional development usually provides teachers opportunities to learn through reading books and resources, listening to lectures, and watching visual resources such and video and demonstration lessons.

Phase 2 professional development, on the other hand, focuses on developing *expertise* for teaching mathematics: skill for developing lessons for particular students, questioning techniques, skill for designing and implementing formative assessments, foresight for anticipating students responses to questions, and skill for purposeful observation of students during a lesson. To develop such expertise for teaching, teachers should plan a lesson carefully, teach the lesson based on the lesson plan, and reflect upon the teaching and learning based on careful observation. Japanese teachers and educators usually go through this process using *Lesson Study* (Firestone, 1996; Huberman & Guskey, 1994; Little, 1993; Miller & Lord, 1994; Pennel & Firestone, 1996).

Japanese lesson study model

The practice of lesson study originated in Japan. Widely viewed as the foremost professional development program, lesson study is credited with dramatic success in improving classroom practices for the Japanese elementary school system (Lewis, 2002b).

Lesson study embodies many features that researchers have noted are effective in changing teacher practice, such as using concrete practical materials to focus on meaningful problems, taking explicit account of the contexts of teaching and the experiences of teachers, and providing on-site teacher support within a collegial network. It also avoids many features noted as shortcomings of typical professional development, e.g., that it is short-term, fragmented, and externally administered (Akihiko Takahashi & Yoshida, 2004).

Lesson study promotes and maintains collaborative work among teachers while giving them systematic intervention and support. During lesson study, teachers collaborate to: 1) formulate long-term goals for student learning and development; 2) plan and conduct lessons based on research and observation in order to apply these long-terms goals to actual classroom practices for particular academic contents; 3) carefully observe the level of students' learning, their engagement, and their behaviors during the lesson; and 4) hold debriefing sessions with their collaborative groups to discuss and revise the lesson accordingly (Shulman, 1986).

One of the key components in these collaborative efforts is "the research lesson," in which, typically, a group of instructors prepares a single lesson, which is then observed in the classroom by the lesson study group and other practitioners, and afterwards is analyzed during the group's debriefing session. Through the research lesson, teachers become more observant and attentive to the process by which lessons unfold in their class, and they gather data from the actual teaching based on the lesson plan that the lesson study group has prepared. The research lesson is followed by the debriefing session, in which teachers review the data together in order to: 1) make sense of educational ideas within their practice; 2) challenge their individual and shared perspectives about teaching and learning; 3) learn to see their practice from the student's perspective; and 4) enjoy collaborative support among colleagues.

A framework for designing programs for prospective and practicing teachers

Providing a variety of effective programs and usable resources for prospective and practicing teachers is an important role for universities and school systems. At the same time, it is also important to consider how and when these resources should be provided to the prospective and practicing teachers. Some resources may be appropriate for prospective teachers to help them develop a substantial pedagogical knowledge for understanding a standards-based curriculum.

Some resources might be more useful for developing expertise after the teachers have acquired basic pedagogical skills. Providing all the resources during a prospective teacher program might not be the most efficient way for teachers to use these resources effectively. Some of the resources might be more effective after the teachers gain several more years of experience following their teaching experience in a lesson study.

In order to do so, the first step in designing the programs and resources is to develop a framework to identify the purpose and the target audiences of each program and resource.

Based on the earlier discussion contrasting teacher knowledge and expertise, the three levels of teaching, and the two types of professional development, I propose the following matrix to provide a framework for developing programs and resources for mathematics teacher education:

Table 1: A framework for developing programs and resources for mathematics teacher education

	To become a Level 1 teacher	To become a Level 2 teacher	To become a Level 3 teacher
Phase 1 Professional Development	Strengthen knowledge of mathematics… …through: ・ Studying textbooks and workbooks ・ Using online resources and courses	Acquire knowledge of mathematics teaching and learning— ・ Pedagogical content knowledge ・ Knowledge of the curriculum ・ Knowledge of the students ・ Knowledge of pedagogy… …through: ・ University courses ・ Professional development workshops ・ Online resources ・ Classroom videos ・ Classroom observations, including participating in research lessons	Update knowledge of mathematics teaching and learning… …through: ・ Workshops ・ Evening and summer coursework
Phase 2 Professional Development		Understand the process of lesson study … …through: ・ Designing mock-up research lessons as part of university coursework ・ Lesson study during student teaching	Develop expertise for teaching … …through Lesson Study

Phase 1 for Level 1

Level 1 is the foundation for becoming a teacher of mathematics, since one cannot teach mathematics if one does not know the content. Usually prospective teachers who come to a university or a teacher-training institute already possess the basic knowledge required for Level 1 teaching. If this is not the case, there should be programs to review content knowledge, such as through online courses or individual tutoring. Although they might be needed for only a small number of prospective teachers, such programs could help more people become teachers. Online

courses and resources might be appropriate since the target audience may be smaller number but geographically widely spread.

Phase 1 and Phase 2 for Level 2

Developing knowledge and expertise for Level 2 teaching should be the major focus of university teacher training programs for prospective teachers. Since knowing the content of mathematics is not enough, Level 2 teaching requires the knowledge beyond being able to solve mathematics problems for elementary and middle school students. For example, to teach the formula for finding the area of a parallelogram, Level 2 teachers must know how the formula was developed, why the formula works for any parallelogram regardless its size and orientation, and how the formula is related to other formulas for finding the area of basic geometric shapes.

The knowledge required for Level 2 teaching is a special kind of knowledge for mathematics teachers, and is often called pedagogical content knowledge (Shulman, 1986). Since the knowledge is only required for teaching mathematics, universities and teacher-training institutes should design special courses and resources for prospective teachers of mathematics. In other words, providing regular university level mathematics courses is not sufficient and not appropriate for prospective teachers. Providing dedicated courses and resources for prospective teachers should be the major focus of Phase 1 professional development in preparing Level 2 teachers. At the same time, prospective teachers should develop an understanding of what a good lesson looks like and how to design lessons.

Phase 2 professional development in Level 2 teaching should focus on introducing the idea and the process of lesson study. Engaging in lesson study offers teacher candidates not only practice in developing lessons and teaching lessons based on a plan, but also practice in observing students' learning processes and reflecting upon a lesson.

Phase 1 and Phase 2 for Level 3

Achieving Level 3 is quite demanding and requires extensive Phase 2 professional development. It is essential to understand the philosophy of teaching and learning mathematics, to develop a vivid image of the ideal mathematics class as a model, and to know key instructional techniques for enabling students to learn mathematics independently. Most knowledge and understanding for Level 3 teaching may be obtained through Phase 1 professional development programs such as reading books, listening to lectures, and observing well-designed mathematics classes. However, acquiring the knowledge and understanding is not sufficient to develop the expertise needed for Level 3 teaching. To develop this expertise requires considerable teaching experience, with reflection. Japanese teachers and researchers work collaboratively through lesson study to develop expertise for Level 3 teaching.

Recommendation for universities and school systems

Recognize that knowing mathematics is not enough to help students learn mathematics

Some people still believe that anyone can be a teacher if he or she knows enough mathematics, and therefore teachers do not need any special training to be and to continue being teachers. One of the first steps toward having effective mathematics teachers in the classroom is to help policy

makers and leaders in society who have the opportunity recognize the needs for establishing supporting structures not only for prospective teachers but also for practicing teachers.

Research

Research is essential to the design of programs and resources provided for teachers. The first step toward establishing effective programs and usable resources would be to study the needs of the prospective and the practicing teachers. This could be accomplished by using the proposed framework for developing programs and resources for mathematics teacher education. Once the programs and resources are established, the next step would be to examine their effectiveness through empirical research. Since the ultimate goal of these programs and use of resources is to promote better mathematical skills and understandings for the students, the research project would require substantial time and effort. Although research might not be able to contribute to immediate results of the university's efforts, actionable research should always be the foundation of the decision making for world-class universities.

Resources and programs

After establishing effective programs and useful resources, universities and school systems traditionally provide these only to their enrolled students and teachers. The concept of open courseware[2] is to share high quality educational materials with a wider audience. A collaboration of more than 200 higher education institutions and associated organizations from around the world established the Open Courseware Consortium and created a broad open educational content using a shared model. In fact, the APEC Human Resource Development Working Group uses the concept of the open courseware for the Knowledgebank web site using Wiki technology[3].

[2] http://www.ocwconsortium.org/

[3] http://hrd.apecwiki.org/index.php/Main_Page

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