Executive Summary

Adults often mention a particular teacher who inspired them as a student to persevere and thus fulfill their personal potential and dreams, providing support for the popular idea that “Teachers make a difference” (p. 1, National Research Council). At the same time, appreciation expressed for individual teachers does not always generalize to the teaching profession as a whole. Teacher preparation programs do not always share the respect afforded to other professional preparation or their economic rewards. Indeed, across the six countries involved in this study these varied considerably.

Insights from the Third International Mathematics and Science Study (TIMSS) curriculum analyses highlighted the important role teachers have with respect to differences in student achievement (Schmidt, McKnight, Houang, Wang, Wiley, & Cogan, 2001). Given the important role that teachers have in selecting topics for classroom instruction, organizing and providing classroom learning opportunities, and the great range of student achievement differences observed in international comparative studies, a critical question arises: how are teachers prepared in each country to teach the curriculum they will be required to teach? This question led to the present study with its focus on middle school – lower secondary, internationally – mathematics and explains the set of countries that participated: Bulgaria, Germany, South Korea, Taiwan, Mexico, and the U.S. These countries represent a range of industrialization, economic standing, and student performance on comparative assessments such as TIMSS and PISA. This book is based on findings from Mathematics Teaching in the 21st Century (MT21), an international study conducted by the authors and funded by the National Science Foundation to examine the preparation of middle school mathematics teachers.

More than 2,600 future teachers were surveyed. MT21 sampled at the institutional level within countries. The goal was to obtain a reasonably representative sample for each country that included the variation found across all teacher education institutions in the country. Four criteria were applied to accomplish this goal: type, size, location, and selectivity of teacher education institutions. Within these institutions the goal was to survey all eligible future teachers.

Contexts for Teaching Middle Grades Mathematics

The central task of teaching is very similar in each of the six countries studied. Indeed, future teachers reported very similar views about how they might actually teach students in
classrooms. Nonetheless, despite sharing many common goals and approaches the context of teaching in each country differed. Mathematics is a required subject in the middle grades and is considered a basic education required of all students through grade 8 in all six countries. However, in one country (Mexico) only about 50 percent continue to upper secondary while virtually all students do so in the other five countries. In addition, the typical number of classroom sessions for a middle grades mathematics teacher ranges from as few as 17 (Taiwan) to as many as 40 (Mexico). Actual classroom instruction time for students also varies but is much more consistent than the amount of classroom instruction expected for teachers. As to what middle grades mathematics teachers may teach, the official mathematics curricula in these six countries exhibited many common intentions but also many sharp differences for key middle grades topics such as properties of common and decimal fractions; exponents, roots, radicals; and patterns, relations, functions.

Preparing to Teach Middle Grades Mathematics

Preparing highly qualified teachers is a matter of concern and public policy in every society that sponsors public education and, hence, undoubtedly the central goal of teacher education in every country and in every institution entrusted with this mission. Towards this end, each teacher preparation institution organizes a set of courses and experiences that are designed to equip future teachers with a set of competencies that they can take with them into the classroom. Professional competencies include cognitive abilities and affective-motivational dispositions. The desired cognitive abilities necessary for a mathematics teacher to be successful in the classroom are generally agreed upon in the literature and encompass three types of abilities: 1) mathematics content knowledge, 2) pedagogical content knowledge related to the teaching and learning of mathematics, and 3) general pedagogical knowledge related to instructional practices and schooling. Professional beliefs are another component of competencies as they bridge between the cognitive abilities and the actual practice of classroom teaching. Such beliefs include general epistemological beliefs about the nature of mathematics and the nature of schooling, as well as specific behavioral intentions about instruction and classroom management.

Formal government standards specify who may teach what school subjects to which group of students. Accordingly, teacher education programs vary according to these official policies. In three countries, middle grades mathematics teachers are prepared as mathematics specialists certified to teach at the secondary level. The secondary level may begin as early as grade 5 (Bulgaria) or as late as grade 7 (Taiwan and South Korea). One country prepares middle grades mathematics teachers as mathematics specialists for those grade levels, i.e., 7 to 9, only (Mexico). Two countries prepare middle grades mathematics teachers through a program certifying teachers to teach up to grade 8 (the U.S.) or 10 (Germany). In Germany and in the U.S. future teachers are sometimes also prepared as mathematics specialists.

Future teachers who were completing a middle grades mathematics teacher preparation program responded to a comprehensive survey about their opportunities to learn (OTL) specific topics in each of four areas: formal mathematics; mathematics pedagogy; general pedagogy; and practical school-related experiences. Most students preparing to be middle grades mathematics teachers were under 25 years of age in their final year of teacher education although the
proportions of these ranged from a low of four percent (Germany) to a high of 94 percent (Bulgaria). The time students took to complete their mathematics teacher preparation program was typically about four years in most countries but was reported to be as much as nine years (Germany). The increased time in teacher preparation and older ages of those responding from Germany is explained by an additional two years of practical school experiences conducted in small pedagogy centers affiliated with local schools. Responding future teachers from Germany were all at the end of their first or second year in this second institution having already completed their academic preparation.

The OTL in each of the four survey areas varied appreciably across the 34 institutions studied, with the institutional patterns further clustering by country. These patterns reflect different visions of teacher preparation. In addition, these differences in OTL are related to differences in performance with respect to our measures of the major cognitive and belief competencies of concern in teacher education. These relationships were documented both at the individual potential future teacher level and at the institutional level. They serve as evidence to suggest that the variations in course-taking across potential future teachers and institutions are related to variations in their knowledge and beliefs. Indeed, the unmistakable conclusion is that teacher education matters.

**Balancing the Emphasis among Aspects of Teacher Preparation**

All of the 34 institutions addressed the four OTL areas in some way. What varied was the total amount of time spent on course requirements (as measured in total clock hours), the amount of coursework in each of these areas, and the number of different types of practical school-related experiences. The total instruction time in clock hours varied greatly across the six countries from a low of around 1700 hours to a high of over 3500. For example, Taiwanese institutions on average required over 550 more clock hours over the four years of teacher preparation than did U.S. institutions. It is essential to point out that some of these differences, if not the majority of them, stem from different governmental policies that regulate teacher education, but this insight only serves to underline the important differences documented.

**Mathematics**

Across the six MT21 countries, the typical degree of emphasis on mathematics as a percentage of total instruction in teacher preparation ranged from as little as none or 13 percent time to nearly 60 percent. Taiwanese sampled institutions on average required that over half (56%) of the clock hours be allocated to the study of mathematics. The secondary preparation programs in the U.S. required on average 30% while the elementary programs required only 20%. Germany was very similar to the U.S. but potential future teachers there are also required to obtain preparation (academic major) in one additional subject area. Mexico required no formal mathematics except what was provided in their mathematics pedagogy courses. A basic calculus sequence and a linear algebra course were taken by virtually all of the sampled Taiwanese potential future teachers, which was also true for those sampled in South Korean for whom mathematics instruction represented 43% of their total course-taking. Bulgaria, however, required the largest proportion of mathematics course-taking of all – nearly 60%.
Sampled future teachers in the two Asian countries also took more advanced coursework such as analysis, differential equations, and abstract algebra than did those in any of the other countries, including Bulgaria or the U.S. There were clear differences in OTL related to formal mathematics. Statistical analyses suggested significant and large relationships of such OTL to the MT21 mathematics knowledge test at both the individual and the institutional level. The opportunities related to higher mathematics knowledge scores at the individual level included coursework primarily in linear algebra and calculus but also abstract algebra and advanced mathematics that included analysis, topology and differential geometry. Coursework in advanced school mathematics and the more formal aspects of mathematics pedagogy were not related to such performance. This suggests that mathematics content knowledge related to the topics typically taught worldwide in middle school (the knowledge measured by the MT21 mathematics knowledge score) is best developed in formal mathematics courses.

**Mathematics Pedagogy**

Three countries – South Korea, Taiwan, the U.S. and the lower and upper secondary program in Germany – required somewhat the same relative amount of clock hours in mathematics pedagogy (between around 3% and 11% of their preparation time) and their total scores were somewhat similar – 510, 518, 520 and 513. Bulgaria was very similar in their relative allocation of time to mathematics pedagogy but their total score was substantially lower – 440.

Inconsistently, the Mexican and the elementary and lower secondary program in Germany allocated almost a quarter of their preparation time to mathematics pedagogy yet scored only at or below the other countries. The explanation in both cases is likely related to their lower coverage of mathematics and the nature of the MT21 mathematics pedagogy test. The elementary and lower secondary program in Germany is on average about 1.5 years shorter than the lower and upper secondary program. To a large extent this difference plays out at the expense of subject-matter preparation.

The learning opportunities patterns reflected in the amount of coursework required for mathematics pedagogy did not vary as much as it did for mathematics. Formal analyses relating the variation in OTL to the variation in test scores of mathematics pedagogical knowledge were significant, although the estimated relationships were not as strong as they were for the mathematics test.

**General Pedagogy**

Examining the patterns with respect to performance on the general pedagogy measures is yet another story. In contrast to mathematics pedagogy, very large differences in the relative amount of clock hours allocated to general pedagogy were evident across the six countries. Bulgaria and Mexico served as the polar opposites, with Bulgarian sampled institutions requiring only about 5% contrasted with Mexican institutions, which on average required 75% (including practical experiences). Also on the high side were Germany (including the course work obtained during the second phase) and the U.S., with about 25-30% for each of its two programs – elementary and secondary preparation of future middle school teachers. The two Asian countries
allocated around 10% to general pedagogy coursework although, keep in mind, 10% of the total clock hours in Taiwanese institutions could be more than what was allocated in another country.

Using the total mathematics score and the total pedagogy score, an interesting pattern emerges. Taiwanese future teachers performed in the top tier in mathematics and in the middle tier in pedagogy, while Germany was in the middle tier in terms of mathematics but in the top tier in pedagogy. The U.S. was distinct. The mathematics knowledge level of sampled future middle school mathematics teachers placed them in the lowest tier, but they were in the top tier in pedagogical knowledge. However, separating the mathematics pedagogical knowledge into its two components shows the effect of the low mathematics performance. For general pedagogy they remain in the top tier, but for mathematics pedagogy they drop to the low end of the second tier when mathematics knowledge is not conditioned out of the mathematics pedagogy score; when it was conditioned out, they remained in the top tier (with the highest score).

**Practical Experiences**

Also related to both types of pedagogical knowledge as well as to the professional beliefs of future teachers are the variety of classroom-related experiences and the number of weeks of classroom teaching. This clearly indicates the salience of school-related experience. Also, many of the relationships of OTL to these pedagogical test areas and beliefs were defined by the extent of opportunity related to the practical knowledge of how one actively performs in the classroom in terms of instruction (e.g., asking questions that stimulate deeper thought) and classroom management and not just the more theoretical aspects of pedagogy. The results suggest that teacher education as defined by the learning opportunities provided is related to the professional knowledge of future teachers as they leave their teacher education programs.

The real question, then, is not whether such experiences are necessary but rather what are the nature and the extent of the learning opportunities in each of the areas that should be available for future teachers. It is quite revealing but far from conclusive that the countries whose middle-grade students continually perform well on the international benchmark tests have the teachers who have been trained with extensive educational opportunities in mathematics and mathematics pedagogy as well as in the practical aspects of teaching mathematics to their students.

**Professional Beliefs**

Several observations are worth noting with respect to professional beliefs – both the beliefs about the nature of mathematics and schooling as well as beliefs about instructional- and management-related behavioral intentions. In general, it was quite surprising to the research team to learn how much commonality there was in terms of such beliefs and dispositions. To be specific, there was substantial homogeneity of beliefs across all six countries with respect to beliefs about the nature of mathematics teaching and learning. These included agreement on the core objectives of mathematics instruction and on the ways students learn. This suggests there may well exist an emerging global perspective in these areas.

**Conclusion**
Three approaches to teacher education exemplified by Taiwan, Germany and the U.S. emerge from the data. In Taiwan (and South Korea) the students who enter teacher preparation are well prepared mathematically. In other words, these institutions can recruit from the high end of the mathematics achievement distribution. Recruitment is facilitated by teaching jobs that provide high salaries relative to other professions and high social status. The teacher preparation focus requires a high level of formal mathematics. As a result, the output in terms of teacher competence is high in mathematics and more moderate in pedagogy.

By contrast, Germany at a first glance does not seem to achieve an end product in terms of future teachers with a high degree of mathematics knowledge. This conclusion must be moderated by three facts. First of all, the German future middle school teachers have to be prepared in two distinct subject matters. The picture that emerges then changes. At the cost of high achievement in mathematics knowledge, Germany having greater flexibility in its teaching force is able to avoid out-of-field teaching – a problem that is present in many countries. Second, there are two types of preparation programs in which future middle school teachers can be prepared with different program requirements, especially in mathematics. Given the extensive preparation in pedagogy, it is not surprising that the output in terms of pedagogical knowledge is extremely strong. Third, including teacher salaries as an indicator of how attractive the teaching profession is in comparison to other professions in which mathematics is important, Taiwan and South Korea probably attract students with higher entrance knowledge into teacher education.

Finally, the U.S. represents yet a third approach. Recruitment by the institutions secure future teachers whose level of mathematics knowledge is average by international standards and in many cases come from the lower half of the national achievement distribution. The programs (those prepared in elementary, middle school only, and secondary programs) focus heavily on general pedagogy but little on formal mathematics, with the exception of those prepared as secondary teachers. The output is consistent – a low level of mathematics knowledge and a strong level of pedagogical knowledge.

From the U.S. and German perspectives one of the key policy questions centers around whether to maintain the different types of preparation programs for middle school mathematics teachers. In both countries there are differences between the programs both in terms of OTL and in terms of the knowledge level attained. In both countries those prepared in the secondary program have higher levels of mathematics knowledge.

As to whether it is a good idea to prepare these teachers in elementary preparation programs, this becomes an issue of equity. Lower-secondary teachers, even those prepared in elementary and lower secondary programs, have to teach up to Grade 10. These grades are highly important with respect to future opportunities for the students, e.g. whether they can go to a vocational high school or pass the “Abitur” and maybe even attend the university. It seems hard to defend a system where some of the middle school students have better trained teachers than others.

This book provides an international context to explore many of the issues related to how quality teachers may be prepared. It is likely to challenge some of the assumptions of both
educators and policy makers and provide a fresh perspective to address the challenges of public education in each of the cultural contexts represented. OTL emphasis across the areas of mathematics, mathematics pedagogy, and general pedagogy differed across institutions and were clustered within country reflecting, at least in practice, different visions of teacher preparation. Whether any of these provide a preparation for teachers who can produce world class student achievement is an issue only suggested by TIMSS and PISA results.

References: