Chapter 1
Introduction: Exploring the Mathematical Education of Teachers Using TEDS-M Data

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Abstract How does teacher education contribute to the learning outcomes of future teachers? Are there programs that are more successful than others in helping teachers learn to teach? How do local and national policy environments contribute to teacher education outcomes? This chapter introduces the book to readers and invites them to explore these questions across a large number of settings. The chapter illustrates why investigating the impact of pre-service teacher education on teachers' learning outcomes is a necessary component to understanding variation in the quality of teachers who enter the field. The chapter also provides an overview of the Teacher Education and Development Study in Mathematics (TEDS-M) a cross-national study of primary and secondary mathematics teacher education sponsored by the International Association for the Evaluation of Educational Achievement (IEA), and funded by the U.S. National Science Foundation and participating countries. The book includes original work that explores new facets of the TEDS-M methodology and data, along with results and policy implications; and illustrates the challenges and possibilities in engaging in systematic research on teacher education. Because we lack models to frame research on teacher education processes and outcomes, the book seeks to provide guidance to future research in this area by

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The text in this *Overview* contains shortened and slightly edited versions of text that has appeared in the following publications: Tatto et al. (2008). *Teacher Education and Development Study in Mathematics (TEDS-M): Conceptual framework*. Amsterdam, the Netherlands: International Association for the Evaluation of Student Achievement, and Tatto et al. (2012). *Policy, Practice, and Readiness to Teach Primary and Secondary Mathematics in 17 Countries. Findings from the IEA Teacher Education and Development Study in Mathematics (TEDS-M)*. Amsterdam, the Netherlands: International Association for the Evaluation of Student Achievement. Text cited directly or indirectly from those sources will not be made recognizable.

An extensive report on the descriptive findings on the characteristics of teacher education programs and teacher educators in the study can be found in Tatto et al. (2012), and in Tatto (2013). We summarize the key concepts and findings here to orient the reader; the chapters in this part however are original contributions written exclusively for this book.

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outlining the methodology followed by the TEDS-M study as well as findings from secondary analyses of the rich TEDS-M database.

Introduction

How does teacher education contribute to the learning outcomes of future teachers? Are there programs that are more successful than others in helping teachers learn to teach? How do local and national policy environments contribute to teacher education outcomes? This book invites readers to explore these questions across a large number of settings. Although these questions seem simple, authoritative answers are hard to find. Recent work in the United States, for example, has tended to focus more on the learning outcomes of pupils of program graduates rather than the learning outcomes of the prospective teachers themselves (e.g., Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Goldhaber, Liddle, & Theobald, 2013; Koedel, Parsons, Podgursky, & Ehlert, 2015). Yet important research has been done documenting that teachers' knowledge and beliefs are key to pupils' achievement and that teachers' previous preparation should be considered an important policy priority (Campbell et al., 2014; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Hill, Rowan, & Ball, 2005; Metzler & Woessmann, 2012; Wilkins, 2008). Thus, investigating the impact of pre-service teacher education on teachers' learning outcomes is a necessary component to understanding variation in the quality of teachers who enter the field.

This book uses the data collected by the Teacher Education and Development Study in Mathematics (TEDS-M) in 2008. The TEDS-M study is a cross-national study of primary and secondary mathematics teacher education sponsored by the International Association for the Evaluation of Educational Achievement (IEA) and funded by the National Science Foundation and participating countries. TEDS-M focuses on *how teachers are prepared to teach mathematics in primary and lower secondary school.* Consequently, TEDS-M is a study of the variation in the nature and impact of teacher education programs within and across countries.

The purpose of this book is twofold: first, to describe the different phases of the TEDS-M study and showcase original work that explores new facets of the TEDS-M database, along with results and policy implications; and second, to illustrate the challenges and possibilities in engaging in systematic research on teacher education. Because we lack good models to frame research on teacher education processes and outcomes, the book seeks to provide guidance to future research in this area by outlining the methodology followed by the TEDS-M study as well as findings from secondary analyses of the rich TEDS-M database.

The book is organized around the TEDS-M conceptual framework and research questions, and has three parts. *Part I* includes chapters that explore the characteristics of the teacher education programs studied, including the curriculum, the strategies and guidelines that programs use to prepare highly knowledgeable teachers, and the preparation of teachers to meet the needs of diverse learners. This part also includes a study focusing on teacher educators, particularly examining the degree of alignment between the beliefs of teacher educators and future teachers. *Part II* moves to the study of future teachers' beliefs, knowledge, and opportunities to learn. *Part III* includes chapters that address some important methodological issues that arose in TEDS-M and that have not been discussed in depth elsewhere. In particular, chapters in Part III discuss the challenges of creating a common language across settings and countries before undertaking the research; developing rigorous instruments with validity evidence that produce reliable scores, as well as a sampling frame across countries that is sensitive to within-country variation, culture, and norms; and the development of anchor points to convey contextual meaning to the study findings. The last two chapters use TEDS-M data to examine differential item functioning, and to provide validity evidence to support the use and interpretation of TEDS-M assessment results against the expectations included in the CBMS report: The Mathematical Education of Teachers (MET II).[1]

The TEDS-M Framework

The impetus for TEDS-M, conducted in 17 countries, was recognition that teaching in general, and specifically in the so-called STEM subjects, has become more challenging worldwide, as growth in knowledge demands frequent curricular change, and as large numbers of teachers reach retirement age. It also has become increasingly clear that effectively responding to demands for teacher preparation reform will remain difficult while there is lack of consensus on what such reform should encompass. In the absence of empirical data, efforts to reform and improve educational provision in the highly contested STEM arena continue to be undermined by traditional and implicit assumptions. TEDS-M accordingly focused on collecting, from the varied national and cultural settings represented by the participating countries, empirical data that could inform policy and practice related to recruiting and preparing a new generation of teachers capable of teaching increasingly demanding mathematics curricula.

Although future teachers and school systems must place their trust in the numerous and diverse teacher education programs across the world, no comprehensive, authoritative study of the outcomes of teacher education had been carried out at the time that the TEDS-M study took place, and none has been done since. The lack of work in this area made it essential to do a comprehensive study of teacher education's immediate outcomes to identify what knowledge, skills and, dispositions future teachers have close to graduation and when they are declared ready to teach. An important assumption of the TEDS-M study is that the education of teachers is

[1] http://www.cbmsweb.org/the-mathematical-education-of-teachers/

not generic, and that learning to teach occurs within subject contexts. Consequently, TEDS-M is subject-specific and focuses on mathematics teacher education as an area to study.

Two particular purposes underpinned TEDS-M. The first was to identify how the countries participating in TEDS-M prepare teachers to teach mathematics in primary and lower-secondary schools. The second was to study variation in the nature and impact of teacher education programs on future teacher knowledge and beliefs within and across the participating countries. The information collected came from representative samples (within the participating countries) of preservice teacher education programs, their future primary and lower-secondary school teachers, and their teacher educators.

The 17 countries that participated in TEDS-M were Botswana, Canada (four provinces), Chile, Chinese Taipei, Georgia, Germany, Malaysia, Norway, Oman (lower-secondary teacher education only), the Philippines, Poland, the Russian Federation, Singapore, Spain (primary teacher education only), Switzerland (German-speaking cantons), Thailand, and the United States (public institutions only). Across the 17 participating countries, approximately 22,000 future teachers from 751 programs were surveyed and tested. Teaching staff within these programs were also surveyed—close to 5,000 mathematicians, mathematics educators, and general pedagogy educators.

The overall TEDS-M study has three overlapping components:

- Studies of teacher education policy, schooling, and social contexts at the national level;
- Studies of primary and lower secondary mathematics teacher education programs, standards, and expectations for teacher learning; and
- Studies of the mathematics and related teaching knowledge of future primary and lower secondary mathematics teachers.

TEDS-M explored the associations among these components, such as associations among teacher education policies, program practices, and future teacher outcomes as shown in the TEDS-M Conceptual Framework in Fig. 1.1.

Specifically, TEDS-M investigated the following research questions:

1. What are the policies that support primary and secondary teachers' achieved level and depth of mathematics and related teaching knowledge?
2. What learning opportunities, available to prospective primary and secondary mathematics teachers, allow them to attain such knowledge?
3. What level and depth of mathematics and related teaching knowledge have prospective primary and secondary teachers attained by the end of their preservice teacher education?

A common question across these three areas of inquiry concerned cross-national and intra-national variation—specifically, to what extent do teacher education policy, opportunities to learn, and future teachers' mathematics subject and pedagogy knowledge vary across and within countries?

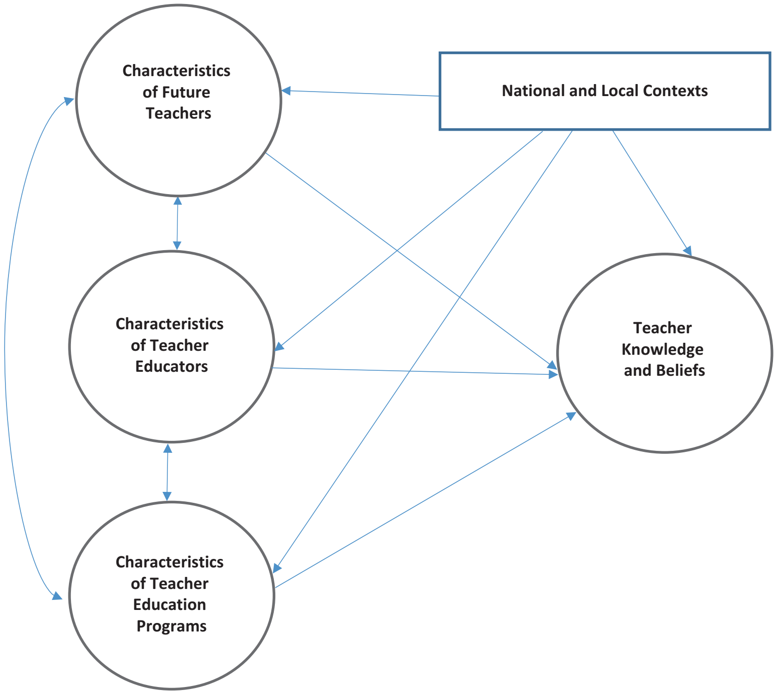

Fig. 1.1 TEDS-M Conceptual Framework

Studying Mathematics Teacher Education: TEDS-M Findings to Date

The main TEDS-M findings are well-documented, both in reports which can be found on the IEA website under the association's complete list of publications available online in the ILSA Gateway (http://www.ilsa-gateway.org/ and search by study 'TEDS-M'), in the ERIC system and in various several articles and special issues.

Although the TEDS-M study has provided and continues to provide new insights into the nature of mathematics teacher education across the participating countries, one of the most important findings for the field of mathematics teacher education, and comparative education more broadly, is the high degree of variation and complexity encountered in the 17 participating teacher education systems. This organizational complexity proved to be more challenging than that encountered in comparative studies of K-12 education within individual countries. Awareness of this complexity led to an understanding that country-by-country comparisons, as done in most international and comparative studies, could be carried out only after efforts to ensure that similar types of teacher education programs were being compared. We discuss these efforts below.

Variation in and Across Countries

The TEDS-M study team did not select countries for participation in the study; rather, countries throughout the world were invited to participate in TEDS-M. The 17 countries that agreed to participate in the study differed with respect to many important geographic, demographic, economic, and educational characteristics. The TEDS-M sample includes very large countries such as the United States of America (U.S.) and the Russian Federation, as well as small countries such as Singapore. These countries vary greatly in financial resources, as measured by per capita income, and in the aggregate size of their economies. In addition, a few have high fertility rates, which lead to rapidly increasing school enrollment, whereas other countries have fertility rates below replacement levels, which could lead to declining school enrollment. Most of the TEDS-M countries have a relatively favorable combination of these interacting characteristics, whereas just a few face serious funding challenges due to growing enrollments. This latter situation is, unfortunately, very widespread outside of the TEDS-M participating countries. TEDS-M is not representative of the world's countries. Instead, it comprises a relatively advantaged, but still diverse subsample from which much can be learned.

Program Variation

The countries that participated in TEDS-M vary in terms of selectivity and status of teachers, and the degree to which teaching mathematics is conceived as needing general or special mathematics preparation. These conceptions of mathematics teaching are reflected in the selectivity of teacher education programs, which is closely related to the supply of beginning teachers: a shortage of candidates who want to be teachers may result in lowering standards of admission and selectivity during and at the end of the programs (as in the United States). In contrast, an oversupply of applicants (as in Chinese Taipei), may lead to tighter admission and more stringent selectivity policy and practices.

TEDS-M provides valuable evidence of diversity in the number, size, and nature of teacher education institutions across the world. The TEDS-M study team surveyed 349 programs that prepare future teachers to teach primary pupils exclusively, 226 programs that prepare future teachers to teach secondary pupils exclusively, and 176 programs that prepare future teachers to teach primary and secondary pupils. The number of institutions that housed these teacher education programs across participating countries ranged from one institution in Singapore that had multiple programs preparing future primary and secondary teachers, to 78 in Poland. The nature of these institutions differs widely within and between countries. Some are Institutes of Higher Education (IHE) such as universities or colleges outside universities; some offer programs only in education; some are comprehensive in the fields of study offered; some offer university degrees; some of these institutions are public and some are private.

The usual way to categorize teacher education programs is according to the design of their opportunities to learn: whether they prepare teachers for primary or secondary schools. However, for TEDS-M, this turned out to be an oversimplification. The terms *primary* and *secondary* do not mean the same thing from country to country. There is no universal agreement on when primary grades end and secondary grades begin. Therefore, instead of relying on an assumed primary-secondary dividing line, TEDS-M constructed a more refined categorization based on a fine-grained analysis of the programs. To ensure that programs with similar purposes and characteristics were being compared across countries, TEDS-M used two organizational variables: grade span (the range of school grades for which teachers in that program were being prepared to teach) and teacher specialization (whether the program was preparing specialist mathematics teachers or generalist teachers). Programs were classified into program-types within countries based on the grade spans for which they prepared teachers, and according to whether they prepared *generalist* teachers or *specialist* teachers of mathematics.

Variation in Opportunities to Learn in Teacher Education Programs

One reason for our effort to classify programs in terms of grade span and specialization is that the resulting groups are likely to have different opportunities to learn (OTL), and the OTL in turn are likely to lead to different knowledge results. TEDS-M found OTL for mathematics, mathematics pedagogy, and general pedagogy depended on the grade level and the curriculum future teachers were expected to teach. For example, programs for future primary teachers gave more coverage to the basic concepts of numbers, measurement, and geometry and less coverage to functions, probability and statistics, calculus, and structure than did programs for lower secondary teachers.

Analogous patterns were also observed among secondary-level teachers. Programs that were intended to prepare teachers to teach higher grades tended to provide, on average, more OTL mathematics than the programs that prepared teachers for the early grades. The findings of this study thus reflect what seems in some countries to be a cultural norm—namely, that teachers who are expected to teach in primary, and especially early primary grades, do not need much mathematics content beyond that included in the primary and secondary school curricula. The pattern among future secondary teachers is generally characterized by more and deeper coverage of mathematics content; however, there was more variability in OTL among those being prepared for the early secondary grades (known in some countries as “middle school”) than among those being prepared to teach Grade 11 and above.

Not surprisingly, the countries with programs that provided the most specialized opportunities to learn challenging mathematics had higher scores in the TEDS-M knowledge assessments. In TEDS-M, future primary-level and secondary-level specialists were found in high-achieving countries such as Chinese Taipei, Singapore, and the Russian Federation; these teachers had significantly more OTL university- and school-level mathematics than primary and secondary teachers in others countries. Opportunities to learn more and deeper mathematics seemed to be related to cultural notions of the knowledge needed to teach mathematics in primary and secondary schools. Yet the question of how much content knowledge teachers need to teach effectively is still an issue of much debate.

TEDS-M offers an opportunity to examine how these distinct assumptions play out in practice. If relatively little content knowledge is needed for the early grades, then less emphasis on mathematics preparation and non-specialization can be justified. The key question is whether teachers prepared in this fashion can teach mathematics as effectively as teachers with more extensive and deeper knowledge, such as that more often possessed by specialist teachers. Although TEDS-M does not provide definitive conclusions in this regard (this question requires the study of beginning teachers and their impact on pupils), it is important to confirm that TEDS-M future teachers who will be mathematics specialists in primary schools have higher knowledge scores on average than their generalist counterparts in the same countries.

Variation Among Teacher Educators

To complement its emphasis on the nature and extent of mathematics content and pedagogy offered to future teachers, TEDS-M surveys included questions for teacher educators about themselves, their students, and their programs. Demographic data on teacher educators at the level collected by TEDS-M fills a gap in the literature and is an important contribution of the study. The TEDS-M data on teacher educators provides insight into the variability of teacher educators across the countries studied in a number of other areas. Among the close to 5000 teacher educators surveyed for TEDS-M, the percentage with doctoral degrees in mathematics ranged from 7% in the Philippines to over 60% in Georgia, Chinese Taipei, Poland, and Oman; the percentage with doctoral degrees in mathematics pedagogy ranged from about 7% in the Philippines to 40% in Georgia. Among these teacher educators, the percentage who reported having experience teaching primary or secondary school ranged from about 20% in Oman to 90% in Georgia. All the teacher educators were asked if they considered themselves mathematics specialists. Their responses varied according to whether the respondent was a mathematician teaching mathematics content to future teachers, a mathematics educator teaching mathematics pedagogy, or a teacher educator teaching general pedagogy. Nevertheless, a surprising number among those teaching mathematics content or mathematics pedagogy described themselves as not being specialists: close to 40% in Chile and the Russian Federation, and close to 50% in Chinese Taipei, Malaysia, and the Philippines. In contrast, close to 90% of those educators in Germany, and Oman declared mathematics as their "main specialty," whereas those in Botswana, Georgia, Poland, Singapore, Switzerland, and Thailand ranged from 70% (in Thailand) to 85% (in Georgia).

Variation Among Future Teachers

As with programs and teacher educators, TEDS-M provided important information on the variability in teachers' demographic characteristics within and across countries. Future teachers being prepared to teach at the primary and secondary school levels in the TEDS-M samples were predominantly female, although there were more males at the higher levels and in particular countries. Most of the future teachers that participated in TEDS-M come from well-resourced homes, leaving low-income families underrepresented in every country in one of the largest occupations that has also historically offered an accessible avenue of social mobility. Many reported having access to such possessions as calculators, dictionaries, and DVD players, but not personal computers—now widely considered essential for professional use—especially teachers in less affluent countries such as Georgia, the Philippines, Botswana, and Thailand. A relatively small proportion of the sample of future teachers who answered the test did not speak the official language of their country (which was used in the TEDS-M surveys and tests) at home, indicating that linguistic minorities may be underrepresented in some countries.

In other respects, the self-reports of future teachers were encouraging. Most future teachers described themselves as above average or near the top of their year in academic achievement at the end of upper secondary school. Among the reasons given by future teachers for wishing to become teachers, liking to work with young people and wanting to influence the next generation were particularly important. Many believed that although teaching is a challenging job, they had an aptitude for it.

Variation in the Outcomes of Teacher Education Programs

Whereas diverse approaches are embodied in each of the programs studied in TEDS-M, it could be argued that they represent variations in the search for the optimal balance among plausible OTL the knowledge needed in mathematics teaching (Ball & Bass, 2000; Shulman, 1987). As suggested in initial reports, there is important variation within and across countries in the outcomes measures used by TEDS-M, namely in the assessments of Mathematics and Mathematics Pedagogy Content Knowledge. We summarize these briefly below.

Mathematics and Mathematics Pedagogy Content Knowledge

There is a clear and unmistakable finding regarding the TEDS-M research question about the knowledge attained by future primary and secondary teachers at the end-point of teacher education: knowledge for teaching mathematics varies considerably among individuals within every country and between countries. The difference in mean mathematics content knowledge (MCK) scores between the highest- and lowest-achieving country in each primary and secondary program group was between 100 and 200 points—one and two standard deviations. This is a substantial difference, comparable to the difference between the 50th to the 96th percentile in the whole group. Differences in mean achievement between countries in the same program group on mathematics pedagogical content knowledge (MPCK) were somewhat smaller, ranging from about 100 to 150 points. So, within each program group, at the end of their teacher preparation programs, future teachers in some countries have substantially greater MCK and MPCK than others.

For each participating country, the results of TEDS-M serve as a baseline for further investigation. For example, content experts may look at the descriptions of the kinds of mathematics and mathematics pedagogy knowledge attained in each program or country and study how changes in OTL may correlate with improved performance. Policymakers may want to investigate ways to encourage more talented secondary school graduates to select teaching as a career, or investigate how teacher preparation programs of the same duration can lead to higher scores on MCK and MPCK. One conclusion that can be drawn from TEDS-M is that goals for improving MCK and MPCK among future teachers should be both ambitious and achievable.

Beliefs

Teachers' actions in the classroom are guided by their beliefs about the nature of teaching and learning, and about the subjects and students they teach. Acknowledging this, the TEDS-M study team gathered data on beliefs from future teachers of mathematics and from the educators charged with the responsibility of preparing them to be teachers. The survey included measures of beliefs about the nature of mathematics (e.g., Mathematics is a set of rules and procedures, Mathematics is a process of inquiry), beliefs about learning mathematics (e.g., by following teacher direction or through student activity), and beliefs about mathematics achievement (e.g., mathematics as a fixed ability). The belief that mathematics is a set of rules and procedures and that it is best learned by following teacher direction have been characterized in the literature as *calculational* and *direct-transmission* (Philipp, 2007; Staub & Stern, 2002). The belief that mathematics is a process of inquiry and that it is best learned by active student involvement is consistent with those described in the same literature as *conceptual* and *cognitive-constructionist*.

Data on beliefs from three groups (future primary teachers, future secondary teachers, and teacher educators) were compared, and, in contrast with the knowledge scales, the differences of substance were not among program groups, but rather among countries. Consequently, the analysis was based on comparisons by country in a way that was not feasible with the knowledge scales. In general, the pattern of beliefs described as a *conceptual* or *cognitive-constructionist* orientation is endorsed by teacher educators and future teachers in all countries, although somewhat more weakly in Georgia. The pattern of beliefs described as *computational* or *direct-transmission* was endorsed by teacher educators and future teachers in Botswana, Georgia, Malaysia, Oman, the Philippines, and Thailand, but not by teacher educators and future teachers in Germany, Norway, and Switzerland. Patterns of responses from several countries (Chile, Chinese Taipei, Poland, the Russian Federation, Singapore, and Spain) were generally consistent with the conceptual orientation, and emphasized the belief that mathematics cannot only be learned by memorizing a series of rules and procedures (*Mathematics as a Set of Rules and Procedures*). The view of *Mathematics as a Fixed Ability* carries with it the implication that mathematics is not for all, that some children cannot and will not succeed in mathematics. This view may have implications for how children are grouped and how they are taught. It is a minority view in all countries surveyed, but still a matter of concern in that it stands in opposition to the apparent international consensus on the need for all children to learn mathematics at a higher level than has generally been the case. This opposition view was supported by future teachers and teacher educators in Botswana, Thailand, Georgia, Malaysia and the Philippines, and rejected in Germany, Switzerland, the United States, and Norway.

There are substantial between-country differences in the extent to which beliefs are held in association with other tendencies. For instance, the program groups within countries endorsing beliefs consistent with a computational orientation are generally among those with lower mean scores on the knowledge tests. However, it would be unwise to generalize from this, for two reasons. First, the sample of countries is quite small. Second, the countries differ greatly from one another both culturally and historically, in ways that may influence both beliefs and knowledge in unknown ways. In some countries scoring high on the MCK and MPCK tests, future teachers endorsed both belief in mathematics as a set of rules and procedures and as a process of inquiry. The TEDS-M findings show that both conceptions, *computational* and *constructivist*, are endorsed in mathematics teacher education, and what is at issue is the appropriate use and balance of each.

Variations in Context and Policy

TEDS-M has shown teachers' careers and working conditions range from those where teachers are carefully selected, well-compensated, and highly regarded to those where there is less selectivity, low salaries, and low status. These careers and conditions are shaped by the two major systems of teacher employment (career-based and position-based) found in the world's public schools, together with various mixed or hybrid models.

Career-based refers to systems where teachers are recruited at a relatively young age to remain in one coherent, clearly organized, public or civil service system throughout their working lives. Teacher education is facilitated by the predictability and stability of careers in these systems. Promotion follows a well-defined path of seniority and other requirements, and teaching assignments follow bureaucratic deployment principles and procedures. Countries able to afford career-based staffing can generally avoid major teacher supply problems and have an advantage in recruiting higher-ability applicants.

Position-based systems take a very different approach to teacher employment. Teachers are not hired into the national civil service or a separate national teacher service. Rather, they are hired into specific teaching positions within an unpredictable career-long progression of assignments. As a result, access is more readily open to applicants of diverse ages and atypical career backgrounds. Movement in and out of teaching to raise children or pursue other opportunities is possible. In these systems, it may be difficult to recruit and retain sufficient numbers of teachers, especially in areas like science and mathematics, where there are attractive opportunities in other occupations.

In short, this distinction between career- and position-based systems has a major impact on teacher education. Since appointment in a career-based system involves a commitment to lifelong employment, such systems are more justified in investing in initial teacher preparation, knowing that the educational system will likely realize the return on this investment throughout the teacher's working life. Often this commitment is made even before the beginner receives any teacher training. In contrast, in position-based systems, such an investment in initial preparation is less justifiable, since the system is based on the assumption that individuals may move in and out of teaching on a relatively short-term basis, and often the graduates of teacher education in such a system never occupy any teaching position at all.

One long-term policy that has increasingly influenced teacher education in a large number of countries worldwide, including those participating in TEDS-M, is to require teachers to have university degrees. Obtaining an all-graduate teaching force, all of whom have higher education degrees (not just diplomas) has been one of the main goals of teacher education policy in many countries over the years and has affected teacher recruitment and the subsequent experience of these teachers once they are employed.

The TEDS-M study team also sought to examine the range of policies affecting teacher education programs, especially those related to accountability concerns, finding great variation in approaches, including the existence of criteria to insure the quality of entrants to teacher education programs, criteria to assess the quality of graduates before they can gain entry to the teaching profession, and accreditation reviews to insure programs' accreditation.

Overall, TEDS-M researchers have found a positive association between the strength of accountability strategies and arrangements and country mean scores in the TEDS-M tests of MCK and MPCK; countries with strong arrangements, such as Chinese Taipei and Singapore, scored highest on these measures. Countries with weaker arrangements, such as Georgia and Chile, tended to score lower on the two measures of future teacher knowledge.

These findings have implications for policymakers concerned with promoting teacher quality. Policies can be designed to cover the full spectrum, from policies designed to make teaching an attractive career to policies for assuring that entrants to the profession have attained high standards of performance. TEDS-M researchers point to the importance of ensuring that policies designed to promote teacher quality are coordinated and mutually supportive. Specifically, TEDS-M provides evidence that countries such as Chinese Taipei and Singapore, that do well on international tests of student achievement such as TIMSS, employ a full range of strategies. They not only ensure high quality of entrants to teacher education, but also have strong systems for reviewing, assessing, and accrediting teacher education providers. They also have strong mechanisms for ensuring that graduates meet high standards of performance before gaining certification and full entry to the profession.

Reform that recognizes these findings is critical. The TEDS-M study team found that all participating teacher education systems were implementing reforms in teacher education, attempting to change their education systems in order to increase the mathematics achievement levels of their students. In the European countries in TEDS-M, changes to entire university systems are underway as a result of the Bologna accord for the creation of a European Higher Education Area. In other countries, such as Malaysia, changes in teacher education toward more advanced levels of education for teachers were precipitated by concerns about the limitations and weaknesses of current mathematics, science, and technology education. Although reform is virtually ubiquitous in the TEDS-M countries, it is important to keep in mind that, as in any cross-sectional study, TEDS-M provides only a snapshot of mathematics teacher preparation in the year 2008–2009, when the data were collected.

TEDS-M's Contribution to the Study of Mathematics Teacher Education

TEDS-M is not only the first large scale comparative international study of teacher education outcomes with representative samples, but in higher education as a whole. Moreover, the surveys were completed with high response rates and coverage of the target populations, in most cases meeting the very high IEA standards for sampling and response rates. In the instances where the IEA standards were not met, the response rates still compared favorably with general experience in higher education surveys, especially surveys in which the targeted participants are all volunteers.

TEDS-M thus lays the foundation for future rigorous national and cross-national research in teacher education, making available a common terminology, sampling methods tailored to teacher education, instruments, and analyses that can be adapted and improved for use in subsequent teacher-education studies, whether they be in mathematics or in other areas. TEDS-M has also served to develop strong research capability within the countries that participated in this study. Finally, the TEDS-M database has continued to contribute to this new line of research by enabling secondary analyses by researchers around the world.

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