Advances in Mathematics Education

Sigrid Blömeke
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William H. Schmidt *Editors*

International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn

TEDS-M Results

Springer

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ISSN 1869-4918 ISSN 1869-4926 (electronic)
Advances in Mathematics Education
ISBN 978-94-007-6436-1 ISBN 978-94-007-6437-8 (eBook)
DOI 10.1007/978-94-007-6437-8
Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2013949543

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Series Preface

The sixth volume of the series Advances in Mathematics Education differs from other books in this series in several respects. Based on an issue of ZDM published recently the book offers results from the international comparative study TEDS-M 2008 (Teacher Education and Development Study—Learning to Teach Mathematics). TEDS-M is a comparative study of teacher education examining the preparation of teachers of mathematics at the primary and lower secondary levels at the end of their study. The study was carried out under the auspices of the International Association for the Evaluation of Educational Achievement (IEA).

TEDS-M focuses on the connections between teacher education policies, practices and outcomes. The main goal of TEDS-M is to show whether and how much teacher preparation policies, programs, and practices across the world contribute to the capability to teach mathematics well in primary and lower secondary schools. TEDS-M analyses teacher education under three following perspectives: at the level of the country context, that comprises studies of teacher policies, programs and practices on the national level; at the institutional level analyses of curricula and practices of teacher preparation, including standards and expectations for teacher learning and at the individual level the impact of teacher preparation on the knowledge, skills and dispositions acquired by future teachers.

These three-folded goals in connection with nationally representative samples of primary and lower secondary mathematics teachers in their final year of teacher training from 16 countries as well as representative samples of teacher educators and training institutions made this study to a real challenge. The papers in the sixth volume of Advances in Mathematics Education describe the theoretical framework of the study, design and test instruments and results at different levels and from different perspectives. The book samples papers, which had already been printed at other places and combines them with newly written chapters based on new data analyses.

The book provides an insightful overview on the efficiency and effects of teacher education internationally, which the reader will hopefully find interesting.

Hamburg, Germany — Gabriele Kaiser
Missoula, USA — Bharath Sriraman

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Part I
Introduction

Framing the Enterprise: Benefits and Challenges of International Studies on Teacher Knowledge and Teacher Beliefs—Modeling Missing Links

Sigrid Blömeke

Abstract This book presents a collection of the most important papers that examined—based on data from the "Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M)"—the outcomes of mathematics teacher education in terms of knowledge and beliefs, the relationship between opportunities to learn (OTL) during teacher education and outcomes, as well as the relationship between the future teachers' background and teacher education outcomes. As an introduction, in this chapter the challenges of taking on an enterprise like TEDS-M are discussed. Firstly, the value-added of international studies and their methodological limits are reflected. Second, different approaches to examine teacher education outcomes over time and across countries are presented. In a third step, missing links on the continuum of teacher learning from teacher education through induction up to continuous professional development are modeled. Thus, the state of research on teacher knowledge and teacher beliefs is summarized in a new way. Finally, the practical relevance of studies such as TEDS-M is demonstrated by using their instruments as tools for learning during teacher education. The objective of these four parts is to frame the book by placing its results in the broader context.

Keywords Teacher education · Teacher induction · Continuous professional development (CPD) · Teacher competence · Teacher knowledge · Teacher beliefs · Teaching performance · Generalizability · Validity · Large-scale assessment · International comparison

In a first review of the state of teacher-education research for the "ZDM—The International Journal on Mathematics Education" in 2008, we summarized the state as follows: "Teacher-education research lacks a common theoretical basis, which prevents a convincing development of instruments and makes it difficult to connect studies to each other" (Blömeke et al. 2008a). Since then, research on future and practicing teachers has developed. The "Teacher Education and Development

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S. Blömeke et al. (eds.), *International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn*, Advances in Mathematics Education,
DOI 10.1007/978-94-007-6437-8_1,

Study: Learning to Teach Mathematics (TEDS-M)" was particularly important in this context.

TEDS-M was the first study in which primary and lower secondary mathematics teachers' competence in their last year of teacher education was examined with direct measures, and this with representative samples and across countries (Blömeke et al. 2011, 2012; Tatto et al. 2008, 2012). TEDS-M was carried out under the supervision of the "International Association for the Evaluation of Educational Achievement (IEA)".[1] The ranking of the countries and teacher education programs provided benchmarks to evaluate the quality and effectiveness of teacher education in 16 countries.

The pioneering work of TEDS-M has paved the way for a special ZDM issue in 2012 that in turn provided the basis for this book. It presents a collection of the most important papers that examined—based on TEDS-M data—the outcomes of mathematics teacher education in terms of knowledge and beliefs, the relationship between opportunities to learn (OTL) during teacher education and outcomes as well as the relationship between the future teachers' background and teacher education outcomes. Besides the ZDM papers, core articles from other journals were included if they covered crucial research questions and if the copyright regulations allowed us to do so. All papers were adjusted for the purpose of this book to develop a coherent reading.

As an introduction, we discuss the challenges of taking on an enterprise like TEDS-M. We reflect firstly on the value added of international studies and on their methodological limits (Sect. 1). Second, we present different approaches to examine teacher education outcomes over time and across countries (Sect. 2). In a third step, we model some missing links by placing TEDS-M as a study on teacher education into the continuum of teacher learning from teacher education through induction up to continuous professional development (Sect. 3). Thus, the state of research on teacher knowledge and teacher beliefs is summarized in a new way. Finally, we demonstrate the practical relevance of studies like TEDS-M by using their instruments as tools for learning during teacher education (Sect. 4). The objective of these four parts is to frame the book by placing its results against the broader context.

1 Benefits and Challenges of International Studies on Teacher Education

1.1 Value-Added Through International Comparisons[2]

During the past two decades, the interest in international comparative studies on teachers, in particular on mathematics teachers has increased (Cochran-Smith and

[1]TEDS-M was funded by the IEA, the National Science Foundation (REC 0514431), and the participating countries. In Germany, the German Research Foundation funded TEDS-M (DFG, BL 548/3-1). The views expressed in this book are those of the authors and do not necessarily reflect the views of the IEA, the participating countries or the funding agencies.

[2]Based on Blömeke and Paine (2008).

Zeichner 2005; Darling-Hammond 2000). Mathematics teachers play a central role in the preparation of future generations' K-12 students. An examination of mathematics teacher education is therefore an important step to ascertain school quality.

The open question is why such studies should be carried out in a comparative way. What is to be learned from an international perspective? Whereas large-scale assessments like TIMSS or PISA regularly examine K-12 achievement as part of monitoring the education system, comparative studies are a rather new approach in teacher research. The idea that there might be global processes that are influencing policies and practices pertaining to teacher education has not been a substantive focus for prior inquiries. However, transnational actors in recent years have grown to become major players in the conversations about teaching and teacher development. Global or transnational agencies such as the World Bank or OECD frame teachers in particular ways through indicator studies, policy briefs, and surveys (Lauder et al. 2012; Robertson 2012). Whether in Germany, China or the USA, the link between school quality in terms of student achievement and teacher quality as teacher education outcome has become a driving force for reform (Takayama 2012).

It becomes therefore imperative to examine teacher education beyond national borders and review research internationally in order to discuss such issues in an evidence-based way. Large-scale cross-national studies can provide information about teacher learning, teacher competence and teaching practices from different countries. They have the power to indicate both global and regional patterns of similarity and difference in these characteristics (Blömeke 2012). The results of comparative studies provide, thus, benchmarks of what level and quality of teacher knowledge can be achieved during teacher education and which country-specific strengths and weaknesses exist.

In many countries, the results of such studies on K-12 student achievement have led to fundamental reforms of the school system. The publication of the PISA 2000 results in Germany, for example (Baumert et al. 2001), one of the first international studies the country took again part in after a long time, and the realization that Germany performed at only a mediocre level—in contrast to the country's self-image—came as a shock. Heated debates among policymakers, researchers, and lay people finally resulted in changes. Similarly, the USA implemented significant reforms in its mathematics school curricula after the so-called "Sputnik shock" and the country's weak performance was confirmed in comparative studies such as SIMS (Pelgrum et al. 1986) and TIMSS (Mullis et al. 1997). Thus, comparative studies of student achievement provided the chance to understand educational phenomena in a new way. Research on teacher education across countries may produce similar effects.

But international perspectives are useful not only for benchmarking. International comparisons also allow us to ask questions in new ways. For example, international research allows us to analyze cultural dimensions of teaching practices and teacher knowledge. By developing international studies, many matters are questioned which may remain unquestioned in national studies. The structure and the content of teacher education depend on a deeper rationale which is a result of factors which may be at least partly cultural. Like the water in the fish's tank, such cultural givens are too often invisible—and international comparisons provide the chance to move beyond the familiar, and to see with a kind of "peripheral vision" (Bateson 1994).

Like everyone else, researchers are embedded in their own culture, and so they often overlook matters of culture. This is particularly the case for teaching and teacher education, given the unique way in which it incorporates or touches upon many different levels of education and stands at the intersection of education and other social, economic, and political forces. The embedded character of the system of teaching and teacher development in a country makes looking beyond that country's experience mandatory in order to recognize the assumptions which drive it and which are all too often taken for granted. The investigation of another teaching system in a foreign country, for example, and the discovery that it is possible to organize the training differently, sheds new light on domestic systems (LeTendre 1999).

It is a methodological challenge to assess teacher competence from a comparative perspective though. Research perspectives have to be adjusted across borders and deeply-rooted educational traditions. Furthermore, it is a challenge to assess the development of knowledge among prospective teachers in the context of a differentiated tertiary education system. Not only do a variety of institutions, teacher training programs and job requirements exist, but also the outcome is hard to define and even harder to measure.

As such, language problems become important in comparative studies as well and are far more demanding to resolve than a "simple" translation of instruments or responses (National Research Council 2003). At one level, language problems are a common, familiar and well-studied aspect of cross-cultural studies, for which there are widely-used conventions of translation and back translation (Hambleton 2002). In teacher education, however, more language-related challenges exist that require attention. They are a problem of cultural boundaries.

In some countries, the language of schooling may vary from the language of the home for many students. Many terms from native languages cannot be translated because adequate English terms are missing and vice versa. It is even difficult to name the process by which future teachers learn their profession: is it teacher education, is it teacher training or is it perhaps teacher preparation? These questions relate to deeper and often tacit assumptions about schooling, teaching, and learning to teach. They are worth examining in detail (for further discussions on the relationship of culture and teacher education see the chapter "Learning from the Eastern and the Western debate: the case of mathematics teacher education" by Kaiser and Blömeke in this book).

1.2 Methodological Challenges: Validity and Generalizability

The theoretical models underpinning teacher education assessments like TEDS-M decompose teacher competence, as the outcome of teacher education, into several facets like content knowledge, pedagogical content knowledge and general pedagogical knowledge (Shulman 1985). The future teachers' achievement in these facets is measured with different tests that allow for rankings on the country level as part of monitoring the teacher education systems.

As sophisticated as these approaches are nowadays and as valuable as decomposing competence into manageable components to facilitate judgments is, the act of decomposition can obscure how a teacher would juggle the various bits together to form a coherent whole. Shavelson (2012) unpacks competence as a complex ability construct closely related to real-life performance. He exemplifies how to make it amenable to measurement in a holistic way by research from business, military, and education in contrast to analytic approaches. It may be worthwhile to follow this line with research projects that compare the results of analytic and holistic teacher assessments.

Assessments intended to capture real-life performance are an issue that has long been discussed (Kane 1992). It seems to be difficult to generalize results from one real-life situation to another, that is, problems with the reliability of empirical results exist (Brennan and Johnson 1995). How representative are, for example, the situations to be worked on in an assessment for the situations to be coped with in real life? TEDS-M is a good example for the difficulties of such questions. Although its conceptual framework looks convincing, a comparison with how California evaluates its pre-service mathematics teachers' knowledge (Wu 2010) reveals that different approaches can be taken. California's Teacher Performance Assessment (TPA) depicts classroom situations according to the state's "Teaching Performance Expectations". Four tasks have to be dealt with: connecting instructional planning to student characteristics, assessment, lesson design, and reflection. These have to be applied to (only) two groups of learners which are not present in the TEDS-M framework at all: English language learners and special education students. This difference reveals different visions of what mathematics teachers are supposed to know and be able to do.

2 Different Approaches to Examine Teacher Education Outcomes

2.1 Historical Development of Studies on Teacher Education Outcomes[3]

Different visions of what teachers are supposed to know and be able to do have driven the different approaches to examine teacher education outcomes over the past decades too. In several international and comparative studies, the intention was to examine teacher competence as the outcome of teacher education. Sometimes this construct was labeled "competence", other times "teacher quality" and sometimes "professional knowledge". The nature of this construct has each time changed.

[3] Based on Blömeke and Delaney (2012).

A first important model that characterized the process of pre-service teacher education and its outcomes can be labeled as "teacher learning". This model included approaches such as learning by observation in a kind of apprenticeship (Zeichner 1980), learning by planning, application, and reflection (Schön 1983) and teacher learning as a craft (Brown and McIntyre 1983). The concept's starting point for modeling teachers' competence was teachers' existing classroom practices.

Similar to this concept was a second one, prominent in the 1990s, in which the cognitive basis of teachers' pedagogical practices started to emerge. The first small-scale comparative studies based on this concept were carried out in the field of mathematics teaching (Pepin 1999; Kaiser 2002). Several studies on—mainly mathematics—teachers and teacher education followed (e.g., An et al. 2004; Ma 1999; Burghes 2008). Important steps were also the ICMI study on teacher education (Even and Ball 2009) and the Topic Study Group on mathematics knowledge for teaching at ICME-11 in Mexico (Adler and Ball 2009). About 50 colleagues from a broad range of countries presented their approaches to measuring (future) mathematics teacher competence (e.g., Kristjánsdóttir 2008; Naik 2008). Much of the teacher research, however, neglected the content domain, focused on beliefs (Bramald et al. 1995; Calderhead 1996) or intended to capture competence by self-reports. Studies including direct measures and cross-country studies are still needed (Brouwer 2010).

More recently, teacher-education research and research on practicing teachers has started to focus on the content-related base of teachers' classroom practice. Besides the studies already mentioned, this paradigm included studies by Rowland et al. (2005), Chick et al. (2006) and the chapters in Rowland and Ruthven (2010). Similar but more analytical is the most recent approach that underpinned also TEDS-M and LMT. This approach was elaborated with respect to the field of mathematics by, for example, Niss (2002) and Schoenfeld and Kilpatrick (2008). In-the-moment decision making in well-practiced, knowledge-intensive domains like teaching can according to them be regarded "a function of their orientations, resources, and goals" (Schoenfeld 2010, p. 187). Mathematics content knowledge (MCK) and mathematical pedagogical content knowledge (MPCK) are the most important resources of mathematics teachers in this context.

Whereas only some differences exist across countries how precisely to define MCK, much more differences exist with respect to MPCK and, in particular, with respect to further facets of teacher competence that are not cognitive. Affective-motivational facets such as orientations and goals or meta-cognitive facets like self-regulation are in some studies supposed to be decisive in the teaching process because they provide orientation how to perceive and analyze a classroom situation whereas they do not at all get recognized in others. These differences in research methodology reflect differences in the views on teaching outcomes, whether they are long term or short term, whether they are focused on factual student knowledge or include complex cognitive skills like problem solving or affective characteristics like student motivation.

2.2 The Role of Teacher Beliefs[4]

Research suggests that beliefs are a crucial part of mathematics teachers' competence (Calderhead 1996; Richardson 1996). As beliefs are thought to guide perception and actions, they can be regarded crucial for the application of knowledge in classroom situations (Leder et al. 2002; Thompson 1992) and they can be conceptualized as a bridge between knowledge and teaching (Stipek et al. 2001; Voss et al. 2011). Furthermore, some studies reveal that teachers' beliefs are relevant for the outcomes of teaching in terms of student achievement in mathematics (Dubberke et al. 2008; Staub and Stern 2002). Teacher beliefs and meta-cognitive dispositions have probably to be included in order to develop a full model of teacher competence and to increase the validity of empirical studies.

Despite the extensive debate on beliefs, a precise definition of the belief construct, as well as clear-cut differentiations from other concepts such as convictions, attitudes or perceptions, have not yet been established (Hofer and Pintrich 2002; Pajares 1992). Richardson (1996, p. 103) developed a widely-followed although broad definition, in which beliefs are seen as "psychologically held understandings, premises, or propositions about the world, that are felt to be true". Comparative large-scale assessments in the context of (future) teachers, like MT21 or TEDS-M, are based on this definition. They understand beliefs in addition as socially and culturally shaped mental constructs, which are acquired in educational settings with different historical traditions that vary significantly between countries. Thus, cultural patterns are expected that are related to overall models of relationships in a society. Hofstede (1986), for example, distinguishes between collectivistic and individualistic societies. In individualistic societies, learners are perceived more strongly as autonomous subjects acquiring knowledge mainly independently on their own than in collectivistic countries where familial relationships are an important driving force for learning (Triandis 1995).

Empirical studies of beliefs have primarily focused on students (Grigutsch 1996; Leder et al. 2002) and on practicing teachers of primary and secondary schools (Dubberke et al. 2008; Peterson et al. 1989). The study "Mathematics Teaching in the 21st Century" (Blömeke et al. 2008b; Schmidt et al. 2011) was the first study to compare future lower-secondary teachers' beliefs in several countries, namely Bulgaria, Germany, the USA, Mexico, Taiwan and South Korea. The MT21 results revealed country-specific patterns in the teachers' beliefs. The "Teaching and Learning International Survey (TALIS)" (OECD 2009) examined practicing teachers' epistemological beliefs on teaching and learning pointed in the same direction. In individualistically oriented societies, for example Australia and Northwest European countries, constructivist beliefs on teaching and learning were more prevalent. In contrast, in collectivistically oriented societies, such as Malaysia and South American states, transmission views have more strongly been articulated by teachers. Beliefs of Eastern European teachers and South Korean teachers were situated between both groups of countries (Klieme and Vieluf 2009; Vieluf and Klieme 2011).

[4]Based on Felbrich et al. 2008.

TEDS-M continued examining the beliefs of future teachers across countries (for more information see the chapter "The Cultural Notion of Teacher Education: Future Primary Teachers' Beliefs on the Nature of Mathematics" by Felbrich, Kaiser and Schmotz in this book).

3 Modeling Missing Links

3.1 The Continuum of Teacher Learning After Pre-service Teacher Education: Teacher Induction[5]

Initial teacher education sets only a first tone for the development of teacher competence. The next years as beginning teachers are regarded decisive for further professional development (Feiman-Nemser and Parker 1990; Veenman 1984). Beginning teachers have to cope with an almost overwhelming task: applying the knowledge gained during teacher education to different and complex classroom situations with multidimensional challenges occurring at high speed (Sabers et al. 1991). Developing teaching quality during these first years is therefore an important task for all education systems. Evidence suggests that the quality of the school environment is important at this stage of a teaching career (Darling-Hammond and McLaughlin 1995). However, it is widely unknown which characteristics of the school environment are relevant and how they are related to different indicators of teaching quality.

Induction is a necessary phase in learning to teach. It marks the period following pre-service teacher education. Beginning teachers take for the first time full responsibility for regular classes of elementary or secondary students. This experience of being a novice and learning how to teach within an established community of practice may be different from school system to school system and be labeled and understood differently, but it is all induction.

Of the 25 countries reviewed for "Teachers Matter" (OECD 2005), only ten had mandatory induction programs (Australia, England and Wales, France, Greece, Israel, Italy, Japan, Korea, Switzerland, and Northern Ireland). In six countries, schools can elect to offer induction programs. In the other countries, there were no induction programs at all. A similar variation was found in terms of where these were housed. Induction programs were most commonly offered by schools, but in four countries (Israel, Japan, Switzerland and Northern Ireland) induction programs were provided jointly by teacher education institutions and schools. The length of the programs varied from seven months in South Korea to two years in Switzerland. An ETS review of induction in 8 countries revealed further variation depending on the amount of practical experiences during pre-service teacher education (Wang et al. 2003, p. 28). Some teacher education programs, such as those in Switzerland, provided extensive field experience; others provided little time in the field (South Korea and France). Induction complements these approaches and thus varies.

Several purposes for induction exist: connecting theory to practical experiences where this had not happened during pre-service education, improving teaching, re-

[5]Based on Blömeke and Paine (2009), Paine and Schwille (2010).

ducing attrition, supporting novice teachers' well-being and responding to mandates and practical needs of educational systems (Huling-Austin 1990). Induction appears to occupy a special place, uniquely influenced by looking backward to pre-service teacher education and forward to the career of teaching (Feiman-Nemser 2001). Paine et al. (2003) argue teacher induction is about building "something desirable: effective teachers, a strong teaching force, a vital profession, and optimum learning for students in schools" (p. 80).

One important finding is the dual commitment to focusing on both improving teaching quality and personal development. Britton et al. (2003) identified seven categories of content that induction programs offered—with variation in the specifics of time and focus: effective subject-matter teaching; understanding and meeting pupils' needs; assessing pupil work and learning; reflective and inquiry-oriented practice; dealing with parents; understanding school organization and participating in the school community; and understanding oneself and current status in one's career.

It is very common that a beginning teacher has the opportunity to work one-on-one with an experienced teacher through their induction program. The OECD (2005) report found that in 15 countries where programs of induction occur, 13 have mentors as either the key person with whom the novice works or as one of the main people responsible for supporting them. The programs share the assumption that one does not learn to teach in isolation. Programs work to help the novice tap into collective experience of the profession through close and sustained contact with a more experienced teacher.

3.2 Continuous Professional Development

Teacher learning continues during the teachers' professional life. The extent of systematic support varies greatly though. While some form of a teacher-learning continuum exists in all educational systems, national teaching forces rely on very different assumptions and structural arrangements to support that learning (Ingersoll et al. 2007; Barber and Mourshed 2007). What is expected of pre-service teachers' competence at the end of their training in some countries, would be seen as part of practicing teachers' learning in others (Paine et al. 2003).

In many countries, national standards for student achievement have been launched by the Ministers of Education during the past 10 years. New demands for teachers emerged (Blum et al. 2006). Continuous professional development that enables the teachers to cope with such a context of change has thus become an important issue. To establish an evidence-based organization of continuous professional development (CPD) is challenging though. We do not have much empirical research. The professional knowledge of pre-service teachers has been researched in depth and from different perspectives. Corresponding research is missing in the field of CPD (Lipowsky 2004; Sowder 2007).

Content-focused coaching (West and Staub 2003) is a model of professional development that assists teacher learning on the job. Expert teachers work as coaches individually or with groups of classroom teachers to design, implement, and reflect on lessons that promote student learning. This is an approach particularly prominent in East Asia. Two of the models' central elements are an emphasis on collaborative lesson planning in pre-lesson conferences and a suggested framework of core issues for the planning and reflection of lessons that aim to focus on pivotal aspects of lesson design in relation to content-specific processes of learning. Quasi-experimental intervention studies in different settings in Switzerland (e.g., Kreis and Staub 2011; Vogt and Rogalla 2009) and in the US (Matsumura et al. 2012) provide evidence on effects of such an approach.

Several countries have launched new approaches, among others Austria (IMST), England (NCETM), Germany (DZLM) and Sweden (NCM). The approaches share that they combine the fostering of CPD activities for mathematics teachers through new types of national CPD institutions with research on the effectiveness of different types of CPD. In 2011 for example, the "Deutsche Telekom Stiftung" launched the German Center for Mathematics Teacher Education (DZLM) to contribute to mathematics teachers' CPD in Germany. A consortium of eight universities that combine research expertise from the fields of mathematics, mathematics education and the educational sciences has established the DZLM. The main objective is to approach CPD from a systemic point of view.

The DZLM aims at implementing a cascade of CPD. In this respect, the training of mentor teachers is considered a core issue, as they are expected to pass on their in-depth knowledge and expertise to fellow teachers. A second core issues is a qualification programs for out-of-field teachers. Another activity concentrates on empowering teacher inquiry and research through supporting local teacher working groups and networks. Such "lesson-study" types of CPD were firstly introduced after the TIMSS 1995 video study as a tool to examine collaboratively as a group of teachers one's own mathematics lessons in order to improve teaching performance and to teach more effectively (Lewis 2002).

In Austria, the IMST initiative has addressed enhancing school quality on a systemic level. IMST is characterized by a consequent bottom-up approach (Krainer 2007). Empirical results reveal that in particular approaches of research-based learning CPD are effective (Krainer et al. 2009). The CPD programs examined followed an approach focused on "action research" (Altrichter and Posch 2007). A four-semester university program "Pedagogy and Subject Didactics for Teachers" (PFL) and the project "Innovations in Mathematics, Science and Technology Teaching" (IMST) increased teachers' self-reported competence and their analytical abilities as measured through video components. Teachers' motivation to teach and students' learning motivation do not change over time.

4 Research on Teacher Competence as a Tool to Improve Teacher Education

Wong, Boey, Lim-Teo, and Dindyal (in this book) make an important point with respect to the practical relevance of studies such as TEDS-M: the released MCK and MPCK items can be used as a training resource. In fact, the Singaporean TEDS-M team prepared a book consisting of these released items, the scoring guides, the Singapore results against international benchmarks and samples of constructed responses. Teacher educators can now use these materials with future teachers by, for example, exploring strategies to remedy misconceptions, designing classroom activities that mirror the scenarios described in the TEDS-M items and linking the assessment items to the TEDS-M framework and thus analyzing conceptions of teacher knowledge. Although the TEDS-M items were originally created as a summative assessment of teacher knowledge at the end of their training, they can so be used as a formative assessment of teacher knowledge.

Another practical use of TEDS-M may be within-country comparisons and further evaluations of local teacher education programs. Whereas the international comparison provides an overall picture that reveals what can be achieved in general, local comparisons may point to features of teacher education easier to transfer from one institution to another. TEDS-M revealed that within most countries, huge between-program disparity existed. This means that within the same cultural context some institutions are more effective than others. They may represent a benchmark. A closer examination of these programs' structure, their mathematics and mathematics pedagogy curriculum, the teaching methods, their selection criteria may put the corresponding features at lower-performing institutions to the test.

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Theoretical Framework, Study Design and Main Results of TEDS-M

S. Blömeke and G. Kaiser

Abstract The comparative "Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M)", carried out under the supervision of the International Association for the Evaluation of Educational Achievement (IEA), provided the opportunity to examine the outcomes of teacher education in terms of teacher knowledge and teacher beliefs both across countries and specifically with respect to mathematics for the first time. This chapter describes the conceptual framework that guided TEDS-M and its study design. The instruments used to measure teacher knowledge and beliefs as well as opportunities to learn (OTL) are described. In addition, core descriptive results, previously only published in German (see Blömeke et al. "Cross-national comparison of the professional competency of and learning opportunities for future primary school teachers", 2010a; "Cross-national comparison of the professional competency of and learning opportunities for future secondary school teachers of mathematics", 2010b (in German)), are described. These results serve as the basis for the other chapters in this monograph. It turns out that teacher education institutions structure their provision of OTL in a way that is consistent with their particular philosophy of what teachers need to know and be able to do. The need to strengthen teachers' content knowledge is one of the dominant ideas that has guided reform efforts in many countries over the past 20 years. The results of TEDS-M which are reported in this chapter are therefore crucial for policymakers. In addition, international comparisons provide benchmarks for national teacher education systems. Countries that do better in TEDS-M may have more effective teacher training programs than countries at the bottom end of the ranking.

Keywords Mathematics content knowledge (MCK) · Pedagogical content knowledge (PCK) · Comparative study · Teacher competence · Teacher beliefs · Opportunities to learn · Teacher education outcomes

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S. Blömeke et al. (eds.), *International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn*, Advances in Mathematics Education,
DOI 10.1007/978-94-007-6437-8_2,

The comparative "Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M)", carried out under the supervision of the International Association for the Evaluation of Educational Achievement (IEA), provided the opportunity to examine the outcomes of teacher education in terms of teacher knowledge and teacher beliefs both across countries and specifically with respect to mathematics for the first time (Blömeke et al. 2011, 2012; Tatto et al. 2008, 2012).[1] TEDS-M was the first large-scale assessment of higher education that included direct testing of outcomes; graduates from 16 countries were surveyed. With this ambitious design, TEDS-M broadens existing research in many respects, which will be elaborated in this chapter.

Teacher education institutions structure their provision of opportunities to learn (OTL) in a way that is consistent with their particular philosophy of what teachers need to know and be able to do. The need to increase teachers' content knowledge is one of the dominant ideas that has guided reform efforts in many countries over the past 20 years (Shulman 1987). Evaluating whether these reforms have been successful is an important step towards assuring the professional quality of those working in teaching. The results of TEDS-M which we will report in this paper are there crucial for policy makers.

In addition, international comparisons provide benchmarks for national teacher education systems. Countries that do better in TEDS-M may have more effective teacher training programs than countries at the bottom end of the ranking. Studying teacher education in an international context is a challenge though. Differences in the structure and content of teacher education include the risk that the data gathered in different countries may not be comparable. At the same time, such differences are precisely that what makes comparative research so valuable. The variety of implementations makes hidden national assumptions visible (for more details on the value added of international comparisons see chapter "Framing the Enterprise: Benefits and Challenges of International Studies on Teacher Knowledge and Teacher Beliefs—Modeling Missing Links" in this book).

The present chapter describes the conceptual framework that guided TEDS-M and its study design. These descriptions have been part of several of our papers in similar versions; most recently they have been part of Blömeke (2012b) with respect to teacher competence as outcome of teacher education and the instruments used to measure teacher knowledge and beliefs as its facets. With respect to the opportunities to learn during teacher education and the instruments to gather data on them, we point to Blömeke (2012a) as well as to Blömeke and Kaiser (2012). For the purpose of this chapter, we revised and adjusted these parts. In addition, we present core descriptive results, which serve as central basis for the other chapters in this monograph, that were previously only published in German (see Blömeke et al. 2010a, 2010b).

[1]TEDS-M was funded by the IEA, the National Science Foundation (REC 0514431) and the participating countries. In Germany, the German Research Foundation funded TEDS-M (DFG, BL 548/3-1). The instruments are copyrighted by the TEDS-M International Study Center at MSU (ISC). The views expressed in this chapter are those of the authors and do not necessarily reflect the views of the IEA, the ISC, the participating countries or the funding agencies.

1 Theoretical Framework

Teacher Competence as Outcome of Teacher Education The TEDS-M concept of teacher education outcomes is based on the notion of "professional competence". Competence is defined as those latent dispositions that enable professionals to master their job-related tasks (see, e.g., Weinert 2001). These dispositions include cognitive abilities—in TEDS-M, this is the future teachers' professional knowledge—as well as convictions and values, in TEDS-M these are the future teachers' professional beliefs. Teacher competence underlies teaching performance in the classroom.

Teacher knowledge as one facet of competence can further be subdivided into different sub-facets which have been frequently discussed in the literature (Shulman 1985; Blömeke 2002; Baumert and Kunter 2006). In his seminal work, Shulman identified three content-related facets and one generic facet, namely content knowledge, pedagogical content knowledge, curricular knowledge and general pedagogical knowledge. A teacher has to develop all four of these to be able to deal effectively with the various challenges of her job: classroom management, assessment, supporting students' social and moral development, counseling and participating in school activities.

The four facets were reduced to three and defined as follows in TEDS-M (for further details, see Tatto et al. 2008):

(1) *Content knowledge* is future primary and lower-secondary teachers' mathematics content knowledge (MCK). MCK includes fundamental mathematical definitions, concepts, algorithms and procedures.

(2) *Pedagogical content knowledge*—including the Shulman facet "curricular knowledge"—is mathematics pedagogical content knowledge (MPCK). This includes knowledge about how to present fundamental mathematical concepts and methods to students adapted to their prior knowledge. Lesson planning knowledge is essential before mathematics instruction in the classroom can begin. The mathematics content must be selected appropriately, simplified and connected to teaching strategies taking into account possible learning difficulties or learning barriers caused amongst others by misconceptions of central mathematical concepts and methods. Knowledge about the way in which students learn should be taken into account when selecting a teaching strategy as well. Such knowledge requires teachers in turn to review students' answers, verbal or written, in the context of the tasks or questions given to them. Teachers should ask questions of varying complexity, identify misconceptions, provide feedback and react with appropriate scaffolding or intervention strategies. Teachers have to consider curricular issues such as the order of topics in primary or lower-secondary curriculum and need to develop their lesson planning in accordance with curricular requirements (Goos et al. 2007; Vollrath 2001). Pedagogical content knowledge may depend on the teaching and learning philosophy of the pedagogical context a teacher is working in and other cultural influences such as differences between Eastern and Western educational traditions (for more details see the final chapter in this book by Kaiser and Blömeke).

MCK and MPCK both cover mathematics, but from different perspectives. Studies by Schilling et al. (2007) and Krauss et al. (2008) demonstrate that while it is possible to distinguish between MCK and MPCK, the two knowledge facets are closely related (for more theoretical reflections on nature of mathematical subject knowledge in teaching and its relation pedagogical content knowledge see Rowland and Ruthven 2011).

(3) According to Shulman (1987) *general pedagogical knowledge* involves, “broad principles and strategies for classroom management and organization that transcend subject matter” (p. 8), as well as generic knowledge about learners and learning, assessment and educational contexts and purposes. Future mathematics teachers need to draw on this range of knowledge and transform it into coherent understanding and skills if they are to become competent in dealing with what McDonald (1992) calls the “wild triangle” that connects learner, subject matter and teacher in the classroom.

Beliefs are in TEDS-M—following a definition developed by Richardson (1996)—understood as “understandings, premises or propositions about the world that are felt to be true” (Richardson 1996, p. 103). This broad understanding is challenged by other approaches emphasizing the experiential and context-bound nature of beliefs though (Schoenfeld 1998). If beliefs are looked at alongside both the subject being taught and the professional task of teaching which needs to be mastered, evidence suggests that there is a link between teacher beliefs and the actual teaching in the classroom (Staub and Stern 2002; Voss et al. 2011). Several studies point out that beliefs are a crucial aspect of a teacher’s perception of teaching situations and her choice of teaching methods (Leinhardt and Greeno 1986; Leder et al. 2002). Thus, they may also serve as an indicator of the type of teaching methods the future teachers will use in the classroom. In addition, empirical evidence exists that beliefs of the teachers influence students’ achievement (Dubberke et al. 2008; Peterson et al. 1989).

Despite the rich literature about beliefs, they are not a well-defined construct. Clear distinctions between terms such as attitudes, perceptions or conceptions on the one hand and cognitive features on the other hand are rare and there exists no consensus about the various definitions and borderlines between these concepts (Goldin et al. 2009). With respect to teachers the distinction towards knowledge—in particular towards pedagogical content knowledge and general pedagogical knowledge—is more heuristic than that it can strictly be kept up (Furinghetti and Morselli 2009).

Several efforts have been made to categorize the belief systems of teachers (Thompson 1992; Op ’t Eynde et al. 2002), for example epistemological beliefs on the nature of mathematics and the genesis of mathematical knowledge or beliefs on teaching and learning processes. Regarding the beliefs on the nature of mathematics, various definitions exist, which share a common ground (Liljedahl et al. 2007). An early classification by Ernest (1989) differentiates between three fundamental views of mathematics: the instrumentalist, the Platonist, and the problem solving view, which is similar to a conception by Dionne (1984), who distinguishes between a traditional view on mathematics (similar to Ernest’s instrumentalist view), a formalist perspective (connected to the Platonist view by Ernest) and a constructivist perspective on mathematics (with similarities to the problem-solving view by

Ernest). Another well-known distinction by Grigutsch et al. (1998) distinguishes between a dynamic and a static view on mathematics, which are further differentiated as follows: static views on mathematics are either formalism-oriented or scheme-related views, the dynamic view on mathematics is either process-related or as new approach, application-oriented.

TEDS-M follows the latter approach and distinguishes between static and dynamic beliefs about the nature of mathematics referring to the sub-classification by Grigutsch et al. (1998). In addition, TEDS-M examines beliefs about the teaching and learning of mathematics separating transmission beliefs from constructivist views as developed by Peterson et al. (1989), and beliefs about teacher education and professional development. Self-related beliefs were not covered in TEDS-M.

With respect to the relationship between teacher knowledge and teacher beliefs, there are theories on the importance of MCK and MPCK when it comes to epistemological beliefs on the nature of mathematics (Schmidt et al. 2011). A certain level of MCK and MPCK may be needed before it is possible to see the dynamic nature of mathematics. These epistemological beliefs, in turn, probably influence beliefs on the teaching and learning of mathematics. The more a teacher is able to see the dynamic nature of mathematics, the more she may prefer student-oriented teaching methods in which students explore mathematics by themselves rather than just listening to the teacher.

Opportunities to Learn During Teacher Education TEDS-M followed the IEA tradition of connecting educational opportunity and educational achievement to determine whether cross-national differences in teacher competence were caused by differences in the teachers' opportunities to learn (OTL) during teacher education (McDonnell 1995). OTL are based on culturally influenced norms on education and intentionally developed by educational policy makers and teacher-education institutions. National and program specifications of OTL therefore reflect particular visions of what future primary and lower secondary teachers are expected to know and be able to do in a classroom and how teacher education should be organized to foster the competence necessary to master these tasks (Stark and Lattuca 1997; Schmidt et al. 2008).

The current state of research points to distinct educational philosophies that influence schooling and teacher education in different countries. Alexander (2001), in his seminal comparative study of primary school education in England, France, India, Russia and the USA, illustrated the subtle and long-term relationship between culture and pedagogy. Tobin et al. (1989, 2009) confirmed these findings with respect to early childhood education in China, Japan and the USA. Leung et al. (2006) were able to demonstrate similar cultural differences with respect to mathematics education in the East and the West.

In the same manner, data from a first comparative study on lower-secondary mathematics teacher-education programs in six countries, the "Mathematics Teaching in the 21st Century (MT21)" study (Blömeke et al. 2008; Schmidt et al. 2011), indicated that heterogeneous OTL profiles exist and that these may have been influenced by context characteristics. In five out of six countries examined, the multiple institutions where teacher education took place tended to cluster together with respect to the OTL offered, suggesting agreement *within* countries but distinct visions *between* countries, thereby reflecting a cultural effect (Schmidt et al. 2008).

OTL are probably related to teacher education outcomes. However, we know already that pure structural features, such as program or degree type, do not appear to have significant effects on short-term outcomes, such as teacher competence, or long-term outcomes, such as teacher retention or student achievement (Goldhaber and Liddle 2011). In contrast, especially in the case of mathematics teachers the evidence increasingly suggests that the *quality* of programs does have an impact on teacher outcomes (Boyd et al. 2009; Constantine et al. 2009).

Content courses in mathematics are assumed to be effective in the literature, as they deliver background knowledge and the body of deep conceptual and factual knowledge necessary to present mathematics topics to learners in a meaningful way and to connect the topics to one another as well as to the learner's prior knowledge and future learning objectives (Cochran-Smith and Zeichner 2005; Wilson et al. 2001).

Knowing the content, however, provides only a foundation for mathematics teaching. Student achievement is higher if strong content knowledge is combined with strong educational credentials (Clotfelter et al. 2007). The importance of *professional preparation*, specifically the understanding of how learners acquire mathematical knowledge, how to teach racially, ethnically and linguistically diverse students and using a wide array of instructional strategies, represents another robust finding of teacher-education research across various studies (Constantine et al. 2009; NRC 2010). Another robust finding on the impact of OTL on the outcomes of teacher education is the quality of the *teaching methods* experienced, in particular, the opportunity to engage in actual teaching practices, such as planning a lesson or analyzing student work, rather than only listening to lectures (Boyd et al. 2009).

Corresponding with these findings, OTL in TEDS-M were framed as content coverage on the one hand, specifically, as "the content of what is being taught, the relative importance given to various aspects" (Travers and Westbury 1989, p. 5). On the other hand, the concept of OTL included quality indicators, such as the teaching methods experienced. Both types of OTL were surveyed via self-reports of the future teachers. The results about how the OTL during mathematics teacher education were shaped in the TEDS-M countries and which effects they had on outcomes are presented in Chaps. 14 through 18 in this book.

It is urgent to discuss such issues of teacher education curriculum in an evidence-based manner (Blömeke and Paine 2008) rather than relying solely on anecdotal experience. For policy makers, the TEDS-M results provide information with respect to where reform is necessary *and* if it is possible to implement changes. For theory development, the results enable us to better understand the nature of teaching and teacher education.