Exploring the Mathematical Education of Teachers Using TEDS-M Data

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Foreword

For more than a century, researchers in mathematics education have had an international dimension to their work. They have attempted to study how mathematics is taught and learned both within and across countries. When, for example, the Commission Internationale de l'Enseignement Mathématique (reincarnated later as the International Commission on Mathematical Instruction) was established in 1908, its first project was to invite reports on the state of mathematics teaching in its member countries. The resulting surveys were used to make cross-country comparisons and stimulate within-country reforms.

During the last half century, international studies of the teaching and learning of mathematics in various countries have grown enormously in scope, number, and quality. Researchers have collected vast amounts of data on course syllabi and textbooks, students' attitudes and performance on mathematics problems, and recordings of instruction in representative samples of mathematics classrooms across multiple countries.

The twenty-first century has seen researchers' attention move beyond the teaching and learning of school mathematics to consider the teachers of that mathematics—what they know and believe about the subject and its teaching as well as how they learn to teach. The Teacher Education and Development Study in Mathematics (TEDS-M) is the largest and best known international study of mathematics teacher preparation. The present book contains reports of exploratory analyses of the TEDS-M data that were primarily produced as the result of a series of workshops to acquaint scholars—especially beginning mathematics education researchers—with the study and the data.

The first section of the book looks at programs to prepare teachers to teach mathematics in primary and lower secondary school. The researchers found considerable variation in programs across and within countries as well as in the backgrounds and preparation of the teacher educators staffing those programs. The TEDS-M data clearly offer a rich selection of program characteristics, and the chapters in the first section only begin to explore the ways in which those characteristics might be related.

The second section focuses on the prospective teachers in the various programs—their knowledge, beliefs, and other characteristics. Again, the researchers found variety across programs and countries, and they were able to discern some provocative patterns connecting what the prospective teachers had learned and what their program had offered them. The cross-sectional nature of the TEDS-M data limited the attention that could be paid to change, but the researchers were nonetheless able to draw some provocative inferences about program outcomes.

The third section addresses methodological issues raised by TEDS-M that concern sampling, instrument development, and validation. The statistical sampling, which involved institutions and populations of prospective teachers and teacher educators in multiple countries, was highly complex, as was the instrument development process. Sophisticated procedures connected to the development of anchor points and to the use of tests of differential item functioning were used to explore how the various assessment instruments were working. Further, the validity of the TEDS-M knowledge assessment was studied through expert judgments of item content against specifications for teacher knowledge. Clearly, this groundbreaking study has made important inroads in the investigation of international comparisons.

In the past few decades, it has become increasingly difficult to recruit participants for empirical studies in education. A researcher in mathematics education, acting alone, cannot hope to acquire a large, let alone a representative, sample of new teachers or of teacher educators from a given country. Studies of representative samples of such groups from more than one country demand the support of international organizations and of national research centers. The TEDS-M data set, therefore, provides a unique resource for researchers in mathematics education. Although the chapters in the present book demonstrate vividly the potential of that resource, they are far from exhausting it. TEDS-M is a gift to you the readers of this book that deserves to be carried forward in the research you will do.

Athens, Georgia Jeremy Kilpatrick

Preface

In this book, we continue to explore the data collected by the Teacher Education and Development Study in Mathematics (TEDS-M) in 2008, and made publicly available in 2012. TEDS-M is the first and only study to date that has been carried out at an international level to explore the outcomes of mathematics teacher education with nationally representative samples of preservice teacher education programs, their educators, and their future teachers at the primary and secondary levels in 17 countries. The study researchers focused on understanding the depth and breadth of mathematics knowledge that future teachers acquire at the end of their preservice programs, essentially making TEDS-M a study of the outcomes of higher education. TEDS-M is the first and only rigorous study where researchers have sought to test a series of hypotheses about what constitutes effective teacher education for future mathematics teachers that had emerged after years of continuous, albeit small-scale, studies of teacher learning. The TEDS-M researchers used a survey methodology to design a comprehensive evaluative research study that could reflect the complexity of the endeavor.

The study was innovative in that the research team developed assessments of future teachers' mathematics content and pedagogical knowledge, among other measures, while collecting and documenting evidence of validity and reliability. This task was only possible with the collaboration of mathematics teacher educators and their students as part of an international and interdisciplinary team of mathematicians, psychometricians, survey and sampling experts, and policy analysts. The TEDS-M International Center received funding from the U.S. National Science Foundation to develop and coordinate the study. Participating countries sought their own funding, and the International Association for the Evaluation of Educational Achievement (IEA) sponsored the study and contributed logistical support.[1] The IEA's network of collaborators, originally founded in 1958, has marked 60 years of

[1] Maria Teresa Tatto then at Michigan State University directed the study. Other organizations involved in the TEDS-M study included ACER, the IEA Secretariat, the IEA-DPC, and Statistics Canada.

exploring different, innovative and rigorous approaches to evaluating educational effectiveness[2] of which this study is an example.

The TEDS-M study was not without challenges. Many factors mediate the ultimate outcomes of teacher education programs. The knowledge that future teachers are able to demonstrate at the end of their preparation in preservice university-based programs is dependent on their previous learning in their primary and secondary schooling, and importantly through their passage in higher education institutions through consecutive or concurrent teacher preparation programs. Further practical experiences in schools through internships or field experiences create yet another level of learning. Evaluating one's own program using an international and comparative assessment creates important opportunities to learn from what other systems are doing and important opportunities for change. As Arthur W. Foshay remarked in the report of the first IEA study ("Educational Achievements of Thirteen-Year-Olds in Twelve Countries"; retrieved from http://www.iea.nl/brief-history-iea):

> If custom and law define what is educationally allowable within a nation, the educational systems beyond one's national boundaries suggest what is educationally possible.

The comparative study of teacher education across different countries also reflects important societal values including conceptions of the knowledge that is important for societies to have, how it is to be acquired, and from whom. Indeed, we believe that the direction a society elects to follow can be identified by the manner in which it treats its teachers and their students.

Although change is typically slow in teacher education, currently we have a combination of stability and fast-paced change resulting from the introduction of alternative routes to preparing teachers, in what seems to be a global movement. It is in this fast-paced environment, where much of the change is driven by market forces rather than by research evidence, that the TEDS-M study provides an important contribution to the field.

The publication of this book serves to celebrate TEDS-M's research findings and methodological advances, to remind us of what is possible and effective in traditional teacher education programs, and to model research that can inform future policy and scholarship. Whereas the critical reader may question the relevance of data that was collected a decade ago, recent research continues to uncover the same problems that TEDS-M highlighted, and the importance of continuing to do the kind of research we undertook.[3] In some cases, the problems have been exacerbated by the proliferation of alternative routes and redefinitions of what counts as a qualified teacher, to the point that scholars have remarked that the project of education in

[2] IEA's work originated in 1958 when a group of scholars, educational psychologists, sociologists, and psychometricians met at the UNESCO Institute for Education (UIE) to discuss problems associated with evaluating school effectiveness and student learning. See http://www.iea.nl/brief-history-iea

[3] See for instance Tatto, M.T., Burn, K., Menter, I., Mutton, T., & Thompson, I. (2018). *Learning to teach in England and the United States: The evolution of policy and practice*. Abingdon, England: Routledge.

universities is in jeopardy.[4] Driven both by teacher shortages and political considerations, popular movements away from formal teacher preparation reveal assumptions about the skills and knowledge necessary to teach effectively; we reject those assumptions and find teaching to be an incredibly complex and difficult art. The lack of a vigorous response from teacher educators to defend the worth of their programs continues to leave the field vulnerable to ideological attacks. We hope that the TEDS-M research will serve as a model to create a basis for inquiry-based learning in teacher education programs.

The purpose of this book, then, goes beyond adding to the key research reports produced by the study,[5] and the already rich research literature based on the TEDS-M data since it was published in 2012, and which can be found in numerous research journals and reports, in books, and elsewhere. We began this book with three purposes in mind. First, we wanted to honor our commitment to the U.S. National Science Foundation to not only make the data publicly available but to enable dissemination of the research, and provide access to our complex database, with a focus on junior scholars and advanced doctoral students. After an initial meeting at Michigan State University, U.S., at the end of 2012, we issued a call for proposals to the national and international mathematics research community. We funded a series of meetings and data analysis workshops for these scholars in exchange for the production of high quality publishable articles and chapters. The call resulted in a number of proposals. These were reviewed by our internal team, during a meeting at Michigan State University, in 2013 and those with the highest quality were selected. We held two meetings with these colleagues in July 2014 in Limerick, Ireland, sponsored by the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), and in July 2016 at the University of Minnesota, U.S. These week-long meetings resulted in the development of 20 paper proposals, which we organized into four symposia proposals for the American Educational Research Association (AERA), Association of Mathematics Teacher Educators (AMTE), the National Council of Teachers of Mathematics (NCTM), and the Comparative International Education Societies Annual Meetings (held in 2015–2016). The symposia were accepted for presentation, and we experienced positive receptions in these conferences. In addition to continue to give visibility to the study, these conferences helped us to advance the work on the papers. We held

[4] See Furlong, J. (2013). Education – An Anatomy of the Discipline: Rescuing the University Project? London: Routledge.

[5] See for instance: Tatto. M.T. (ed.) (2013). *The Teacher Education and Development Study in Mathematics (TEDS-M). Policy, Practice, and Readiness to Teach Primary and Secondary Mathematics in 17 Countries: Technical Report*. Amsterdam: International Association for the Evaluation of Student Achievement. Tatto, M. T., Schwille, J., Senk, S. L., Ingvarson, L., Rowley, G., Peck, R., Bankov, K., Rodriguez, M. & Reckase, M. (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: International Association for the Evaluation of Student Achievement. Brese, F., & Tatto, M.T. (Eds.) (2012). *User guide for the TEDS-M international database. Amsterdam*, The Netherlands: International Association for the Evaluation of Educational Achievement (IEA).

a working meeting in January 2017 to check on the progress of our efforts and to finalize plans for publication. We finished writing the book in March 2017. Once the chapters were written, they were reviewed by the book editors, then by expert statisticians in addition to our own, and once approved, the chapters went through three external editors to ensure clarity and meaning. Once submitted to Springer in mid-2017, the book was reviewed anonymously by six peers following Springer's rigorous review process, and finally approved for publication in early 2018. Second, we wanted the book authors to explore not only issues that have not yet been studied using the TEDS-M database, but also to provide more exploration into aspects of the study that had not been published before, such as the curriculum analysis and the level of belief alignment between future teachers and their educators. Third, we wanted to dedicate a section of the book to discuss in more depth the most important methodological advances achieved by the TEDS-M researchers, such as the sampling strategies and the creation of anchor points to give contextual meaning to the assessments results.

Ultimately, the goal of the book is to inform audiences about how use of the TEDS-M study and data: (a) helps to strengthen the knowledge base to address current national priorities such as increasing the number of fully competent mathematics teachers; (b) helps to understand the nature and contributions of preservice teacher education, as a way to inform policies for selection, preparation, induction, and professional development of mathematics teachers; (c) serves as an example of a scientific approach to the study of teacher education and teacher learning in mathematics; and (d) provides concepts, definitions, measurement strategies, indicators and instrumentation to strengthen the research in this field, and the knowledge base of teacher education effectiveness. We offer this book in the hopes that it will contribute to new studies, and more rigorous scholarship in teacher education, and more generally, in higher education.

July 2018 Maria Teresa Tatto

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We continue to be thankful to the International Association for the Evaluation of Educational Achievement (IEA) for maintaining the TEDS-M database and the website where scholars continue to add work that uses the TEDS-M database and the methods that emerged from the study. We thank the participants in the TEDS-M study including the National Research Centers, teacher educators, and future teachers in Botswana, Canada, Chile, Chinese Taipei, Georgia, Germany, Malaysia, Norway, Oman, Philippines, Poland, Russia, Singapore, Spain, Switzerland, Thailand, and the United States, whose efforts in data collection continue to benefit the field.

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Abbreviations

ACER	Australian Council for Educational Research
AERA	American Educational Research Association
AIC	Akaike Information Criterion
AMTE	Association of Mathematics Teacher Educators
APA	American Psychological Association
BIC	Bayesian Information Criterion
BRR	Balanced Repeated Replication
CBMS	Conference Board of Mathematical Sciences
CCSS	Common Core State Standards
CI	Confidence Interval
CR	Constructed-Response
DIF	Differential Item Functioning
DPC	Data Processing and Research Centre now: IEA Hamburg
EI	Essential Idea
FT	Future Teacher
FPT	Future Primary Teacher
FST	Future Secondary Teacher
FTQ	Future Teacher Questionnaire
ICC	Intra-class correlation coefficient
IDB	International Data Base
IEA	International Association for the Evaluation of Educational Achievement
IHE	Institutes of Higher Education
ILSA	International Large-Scale Assessments
IPQ	Institutional Program Questionnaire
LCA	Latent Class Analysis
MC	Multiple-Choice
MCK	Mathematical Content Knowledge
MET II	The Mathematical Education of Teachers II
MKT	Mathematical Knowledge for Teaching
MPCK	Mathematical Pedagogical Content Knowledge
MSU	Michigan State University

MT21	Mathematics Teaching in the 21st Century Study
NCTM	National Council of Teachers of Mathematics
NCME	National Council on Measurement in Education
NIE	National Institute of Education
NRC	National Research Coordinator
NSF	National Science Foundation
NYC	New York City
OECD	Organisation for Economic Co-operation and Development
OTL	Opportunities to Learn
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
PPS	Probability Proportional to Size
PST	Preservice Teacher
SE	Standard Error
SES	Socioeconomic Status
SMP	Common Core State Standard for Mathematical Practice
SRS	Simple Random Sampling
SSBIC	Sample-Size Adjusted Bayesian Information Criterion
STEM	Science, Technology, Engineering, and Mathematics
TALIS	Teaching and Learning International Survey
TEDS-M	Teacher Education and Development Study in Mathematics
TIMSS	Trends in International Mathematics and Science Study
TP	Teacher Preparation
TPU	Teacher Preparation Unit
TPI	Teacher Preparedness Inventory
USA	United States of America
WinW3S	Windows® Within-School Sampling Software