Part III
Plenary Panels

The TEDS-M: Important Issues, Results and Questions

Konrad Krainer, Feng-Jui Hsieh, Ray Peck and Maria Teresa Tatto

Abstract Until the last decade, international comparative studies in mathematics education focused primarily on the knowledge and beliefs of school students. Recently, the focus has shifted towards research on teachers and teacher education. The Teacher Education and Development Study in Mathematics (TEDS-M) is the first international large-scale study about (initial primary and secondary) mathematics teacher education with 17 countries participating. The importance of large-scale research in mathematics teacher education is mirrored in the decision to organize a Plenary Panel on TEDS-M at the 12th International Congress on Mathematical Education (ICME-12). This paper sketches the background of the study, main program features and major inputs of the Plenary Panel.

Keywords Mathematics teacher education · Content knowledge · Pedagogical content knowledge · Survey research · International and comparative studies

---

K. Krainer (✉)
Alpen-Adria-Universität Klagenfurt, Klagenfurt, Austria
e-mail: konrad.krainer@aau.at

F.-J. Hsieh
National Taiwan Normal University, Taipei, Taiwan
e-mail: hsiehfj@math.ntnu.edu.tw

R. Peck
Australian Council for Educational Research, Sydney, Australia
e-mail: peck@acer.edu.au

M.T. Tatto
Michigan State University, Michigan, USA
e-mail: mttatto@msu.edu

S.J. Cho (ed.), *The Proceedings of the 12th International Congress on Mathematical Education*, DOI 10.1007/978-3-319-12688-3_10

Introduction

Empirical research over recent decades points to the high influence of teachers on students' learning of mathematics. Teachers have been identified as key agents of educational change (Fullan 1993; Krainer 2011). Amongst others, the comprehensive meta-analysis on student learning by Hattie (2003) found that teachers' impact on students' learning is high. Identified factors that contribute to major sources of variation in student performance include the students (50 %) and teachers (30 %) as the most important factors, whereas home, schools, principals, peer effects (altogether 20 %) play a less important role.

Thus intensive research in mathematics teacher education is needed. There is increasing literature about relevant results, however, large-scale findings about the conditions, processes, and effects of mathematics teacher education are rare (Adler et al. 2005). Since Mathematical Content Knowledge (MCK) and Mathematical Pedagogical Content Knowledge (MPCK) play a fundamental role for teachers' effectiveness (Shulman 1986; Baumert et al. 2010), the education of future teachers is a crucial phase in teachers' professional development and a key time for communicating pedagogical innovations, especially because many teachers tend to teach as they have been taught.

The Teacher Education and Development Study in Mathematics (TEDS-M) is the first cross-national data-based study about initial mathematics teacher education with large-scale samples (Tatto et al. 2011, 2012; Loewenberg-Ball et al. 2012). The study collected data from 23,000 future mathematics teachers (primary and lower-secondary) from 17 countries[1] in 2008–2009.

The TEDS-M study drew nationally representative samples and conducted large scale surveys of teacher education institutions, teacher educators, and future teachers to provide substantive information on how institutions organize and prepare future teachers to teach mathematics at the primary and secondary levels. The study also successfully created instruments for measuring the MCK and MPCK of future teachers at the international level in different types of program groups.

TEDS-M was a collaborative effort of worldwide institutions, launched by the International Association for the Evaluation of Educational Achievement (IEA) to address concerns raised by the Third International Mathematics and Science Study (TIMSS). The study is an ambitious attempt to move the study of teacher education and its outcomes in the direction of scientific research with the goal to inform policy. The study was directed by Michigan State University (MSU) in collaboration with the Australian Council for Educational Research (ACER), and National Research Centres in all 17 countries and received important funding from the National Science Foundation (USA), and the IEA.

---

[1] Botswana, Canada (was unable to meet IEA sampling requirements), Chile, Chinese Taipei (Taiwan), Georgia, Germany, Malaysia, Norway, Philippines, Oman, Poland, Russia, Singapore, Spain, Switzerland, Thailand, and USA.

TEDS-M posed questions at three levels: (*a*) *Policies*: What are the teacher education policies of the participating countries that support the mathematics and related knowledge for teaching of their future teachers? (*b*) *Practices*: What learning opportunities in teacher education programs allow future teachers to attain mathematics and related knowledge for teaching? (*c*) *Outcomes*: What is the level and depth of the mathematics and related knowledge for teaching attained by future teachers at the end of their initial teacher education programs? TEDS-M aimed at bringing these three components—policies, practices and outcomes of mathematics teacher education—together. As a result, the findings should be of interest to educational policy makers and researchers, mathematicians and mathematics educators. In the same way that teachers are the key to educational change in schools, mathematicians and mathematics educators are—together with the future teachers themselves—the key drivers of change and innovation in mathematics teacher education.

Comparisons between countries are complex. Outcomes from the study show significant differences in outcome measures between future teachers in different programs in different countries. Since the participating countries have a diverse level of "human development" (formerly "standard of living"), as measured by the Human Development Index (HDI),[2] it is important to take this into account when comparing countries performance in TEDS-M. A study by Blömeke (2011, p. 19) shows a close correlation between the countries' TEDS-M outcome measures and their HDI. However, related to this index, some countries achieved higher than expected in TEDS-M, others lower. The Blömeke study indicates Taiwan, Russia, and Thailand as "overachieving" countries and the USA, Norway, and Chile as "underachieving" countries compared to their level of human development. From the case of Taiwan, we will learn what factors may have a positive influence on the education of future mathematics teachers graduating with high levels of MCK and MPCK. We will also see that Chile and Norway, both performing below their expectations compared to HDI, started reforms as a consequence of their TEDS-M results. Thus, this study offers opportunities to compare with other countries, to look for communalities and differences, as well as for (relative) strengths and weaknesses. However, in order to learn more deeply from other countries and probably to take relevant actions fitting to a country's own context, it is important to look in a more detailed way at program characteristics. TEDS-M is both, a starting point for diverse comparisons among countries, as well as a chance to investigate the quality of teacher education programs and the learning opportunities they offer to future teachers of mathematics.

---

[2] The HDI is a comparative measure of life expectancy, literacy, education, and standards of living for countries worldwide.

The Organization of the Plenary Panel on TEDS-M

The Plenary Panel on TEDS-M at ICME-12 involved four Panel Members: *Feng-Jui Hsieh* (Taiwan), *Konrad Krainer* (Austria, Chair), *Ray Peck* (Australia), and *Maria Teresa Tatto* (USA).

After a short introduction of the Plenary Panel members by *Mi-Kyung Ju* (Korea, Presider), some basic information about TEDS-M and the Plenary Panel by the chair, the other Panel members gave inputs on the following topics:

- Teaching and teacher knowledge: A focus on MCK and MPCK (Ray Peck)
- Teacher education and quality: The performance of Taiwan in an international context (Feng-Jui Hsieh)
- Research in teacher education and TEDS-M: International findings and implications for future policy research (Maria Teresa Tatto)

In order to support the audience in actively following the presentations, each input included a short activity for the whole audience. Given the fact, that in a Plenary Panel with some thousand people it is not easy to have open discussions, the Panel team invited Audience representatives. They are well-known experts with diverse background (mathematics, mathematics education or pedagogy), some having deeper knowledge about TEDS-M: *Deborah Loewenberg Ball* (USA), *Mellony Graven* (South Africa), *Maitree Inprasitha* (Thailand), *Liv Sissel Gronmo* (Norway), *Leonor Varas* (Chile), and *Ildar Safuanov* (Russia).

The Audience representatives were prepared to respond to questions raised by the chair of the Panel each related to the corresponding topic presented by the three panelists.

Teaching and Teacher Knowledge: A Focus on MCK and MPCK

Why Is Teacher Knowledge Important?

Anthony and Walshaw (2009, p. 25) remind us that knowledge helps teachers recognize, and then act upon, the teaching opportunities that come up in the moment. Understanding the ‘big ideas’ of mathematics, permits teachers to recognize mathematics as a ‘coherent and connected system’. This in turn enables them to ‘make sense of and manage multiple student viewpoints’. With strong content and pedagogical content knowledge teachers can help students to develop ‘mathematically grounded understandings’.

Research into student achievement in mathematics has strongly supported the importance and significance of teacher knowledge. For example, Hill et al. (2005), found that the mathematical knowledge of teachers was significantly related to student achievement gains in both first and third grades after controlling for key student- and teacher-level covariates.

Defining Teacher Knowledge in TEDS-M

Teacher knowledge for teaching mathematics in TEDS-M was narrower than that defined by Shulman (1986). It was limited to the knowledge that could be reasonably demonstrated by future teachers in their final year of their programs on a written 60 min assessment. It was also limited to the knowledge that was considered important and culturally meaningful to the 17 participating countries.

In short, the knowledge for teaching mathematics in TEDS-M was confined to two dimensions—mathematics content knowledge (MCK) and mathematics pedagogical content knowledge (MPCK). MCK is mathematics that teachers know and can do whereas MPCK is knowledge about how to assist students to learn mathematics. MPCK is **not** knowledge that ordinary citizens possess. It is theoretical and experiential knowledge learned from studying and working in mathematics education. The focus of MCK in TEDS-M was on the mathematics that the future teachers would be required to teach plus some content 2 or 3 years beyond that.

Because TEDS-M was an international study, the decision was taken to make use of the TIMSS content frameworks for Year 8 and Advanced (Mullis et al. 2005; Garden et al. 2006). The MPCK framework in TEDS-M was developed by the TEDS-M international team, after a review of the literature and was informed in part by the framework used by the Mathematics Teaching in the 21st Century Project (MT21) (Blömeke et al. 2008; Schmidt et al. 2011) which focused on middle school mathematics teacher preparation in six countries. The final version of the MPCK framework was arrived at following a critical review by international experts in the field.

The TEDS-M MPCK framework consists of three sub-domains.

Mathematical curricular knowledge:

> knowing the school mathematics curriculum, establishing appropriate learning goals, identifying key ideas in learning programs, selecting possible pathways and seeing connections within the curriculum, knowing different assessment formats and purposes

Knowledge of planning for mathematics teaching and learning:

> selecting appropriate activities, predicting typical students' responses, including misconceptions, planning appropriate methods for representing mathematical ideas, linking didactical methods and instructional designs, identifying different approaches for solving mathematical problems, choosing assessment formats and items

Enacting mathematics for teaching and learning:

> explaining or representing mathematical concepts or procedures, generating fruitful questions, diagnosing responses, including misconceptions, analysing or evaluating students' mathematical solutions or arguments, analysing the content of students' questions, responding to unexpected mathematical issues, providing appropriate feedback

Measuring Teacher Knowledge in TEDS-M

The TEDS-M study measured knowledge found ‘in the mind’, not that ‘in the body’ as seen and found ‘in our practices’ (Connelly and Clandinin 1988). So, unlike the study by Huckstep et al. (2003), there was not the opportunity in TEDS-M to observe how the mathematics content knowledge of future primary teachers was enacted in practical teaching during school-based placements.

In TEDS-M, content knowledge was assessed by a combination of simple and complex multiple-choice items, together with short and extended constructed response items. Scoring guides for the constructed-response items were refined using responses from the field trial and for most extended constructed-response items, partial credit could be awarded.

Short activity for the audience

In order to sketch the difference between MCK and MPCK items, selected MCK and MPCK examples covering a range of attributes from the released TEDS-M item pool were presented to the audience including item statistics. The audience was invited to participate in providing “informed answers” to the items presented. Their answers were then contrasted with those obtained in the TEDS-M study by using “percent correct” information.

The total score points for each future teacher were analyzed using item response theory (Wu et al. 2007). This enabled four scales for knowledge for teaching mathematics to be constructed: MCK and MPCK for both primary and secondary. Tables and charts were created showing the distribution of country scale scores by program group.

Six “anchor points” were defined and described, two for each MCK scale and one for each MPCK scale. This enabled the achievement of future teachers in each program group to be described against the anchor points. It is hoped that these will provide useful benchmarks for future work. An example of the primary MPCK anchor point follows.

Primary MPCK Anchor Point

> Future primary teachers who scored at this anchor point were generally able to recognize the correctness of a teaching strategy for a particular concrete example, and to evaluate students’ work when the content was conventional or typical of primary grades. They were likely to identify the arithmetic elements of single-step story problems that influence their difficulty. Although future primary teachers at the primary MPCK anchor point were likely to be able to interpret some students’ work, their responses were often unclear or imprecise. In addition, future teachers at the anchor point were unlikely to use concrete representations to support students’ learning or to recognize how a student’s thinking is related to a particular algebraic representation. They generally were unlikely to understand some measurement or probability concepts needed to reword or design a task. These future teachers also were unlikely to know why a particular teaching strategy made sense, if it would always work, or whether a strategy could be generalized to a larger class of

> problems. They were unlikely to be aware of common misconceptions or to conceive useful representations of numerical concepts.

For the 15 countries whose data could be analyzed, nine of the 21 program types across the four defined program groups had the majority of their future teachers at or above this anchor point on the MPCK scale. In some cases, items worth two score points (partial credit items) were able to measure levels of knowledge above and below anchor points. An example of this is item MFC410[3] shown in Fig. 1.

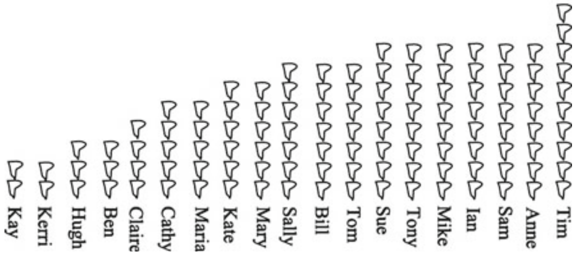
Future teachers at the primary MPCK anchor point were able to achieve partial credit (1 out of a maximum of two score points) with a probability of at least 0.7 on this

MFC410

Imagine that two <primary> students in the same class have created the following representations to show the number of teeth lost by their classmates.

[Mary] drew pictures of her classmates on cards to make this graph.

[Sally] cut out pictures of teeth to make this graph.



From a data presentation point of view, how are the representations alike and how are they different?

Alike:
Different:

Fig. 1 Item MFC410, primary MPCK—sub-domain Enacting, data, two score points

---

[3] Alejandra Sorto, formerly of Michigan State University, is acknowledged for this item.

Table 1 Scoring guide for MFC410

Code	Response	Item: MFC410
	Correct response	
20	Responses that indicate how the representations are **alike** AND how they are **different** 'Alike' examples • They both show the same data/same number of teeth lost • They are both pictorial representations • They are both forms of bar graphs • They are both skewed in the same direction 'Different' examples • Mary has grouped the data/done a frequency tally whereas Sally has not • In Mary's graph each bar or column represents the number of teeth lost, whereas in Sally's graph each column or stack represents a student • Mary's graph is categorized by the number of teeth lost whereas Sally's is person by person	
	Partially correct response	
10	**The 'alike' description is acceptable** but the 'different' description is not acceptable, trivial or is missing 'Alike' example • They both show the same number of teeth lost 'Different' example • Mary's is easier to comprehend than Sally's	
11	**The 'different' description is acceptable** but the 'alike' description is not acceptable, trivial or is missing 'Alike' example • They both made graphs about teeth (Trivial) 'Different' example • Sally made a column for each student whereas Mary made a column for each number of teeth lost	
	Incorrect response	
70	Responses that are insufficient or trivial 'Alike' examples • They are both graphs • Both graphs are about teeth 'Different' examples • Mary used numbers, Sally didn't • Mary's is hard to read, Sally's is easier	
79	Other incorrect (including crossed out, erased, stray marks, illegible, or off task)	
99	**Non-response** (blank)	

item. Only future teachers well above the anchor point were able to achieve full credit on this item. Twenty-nine percent (29 %) of the international sample of future teachers achieved full credit on this item and another 37 % were able to achieve partial credit.

The following Table 1 shows the scoring guide for MFC410. On this item, for the international sample, 29 % were awarded full credit, 37 % partial credit, and 23 % no credit. Eleven percent (11 %) of the international sample of future teachers chose not to respond. The future teachers who achieved partial credit found it harder to say how the representations were different (6 %) than how they were alike (31 %).

This work is described in more detail in recent TEDS-M publications (Senk et al. 2012; Tatto et al. 2012; Tatto 2013).

Views from Audience Representatives

The chair asked two Audience representatives to respond to two questions: "Is what TEDS-M measured valued by the mathematics education community (with a particular focus on the MPCK items)? How well has TEDS-M contributed knowledge to the field?"

Maitree Inprasitha (Thailand) stressed that before TEDS-M, most education faculties in Thailand provided only mathematics content courses (MCK) to future teachers. Now education faculties have started incorporating the idea of MPCK into teacher preparation curriculum. More recently, the Khon Kaen University received a grant to create a network among education faculties in order to redefine courses for future teachers who are majoring in mathematics education. Through this network, mathematics education faculty staff attend seminars and workshops hosted by the education faculty of Khon Kaen university.

Ildar Safuanov (Russia) indicated extensive research arising from TEDS-M in his country. Although Russia has strong MCK and MPCK results, research looks for fields where future teachers have difficulties (e.g., in constructing different interpretations of theoretical contents) in order to achieve improvements. Research also shows that there is a relationship between the quality of education of future teachers and their attitudes to teaching mathematics (e.g., related to an orientation on conceptual models and cognitive-constructivist approaches to teaching mathematics).

Teacher Education and Quality: The Performance of Taiwan in an International Context

Becoming a Teacher in Taiwan

Teaching in Taiwan is attractive in terms of income, working hours, career development opportunities, and job security. As a result, candidates face rigorous evaluation and serious competition throughout the process of becoming a teacher.

Future teachers must obtain a bachelor's degree, complete the initial teacher education curriculum, and finish a practicum before they are evaluated in the yearly-held, national-common teacher qualification assessment. The average passing rates of the qualification assessments for the years of 2007–2010 was 67.4 %.

To get a tenure teaching position, qualified teachers must also undergo a public, competitive, on-site-screening process administered by the school district or individual schools. The screenings are not held only for future teachers, but for all the practicing teachers who want to change schools. The average pass rates of the screenings across the country for the recent years 2007–2010 at the primary, lower secondary and upper secondary levels were 3.5, 11.9, and 6.5 %,[4] respectively (Hsieh et al. 2012a). Regarding the future teachers, the average rates of employment for tenure teaching positions for 2007–2010 were lower than 3.4 % for the primary level and 20.2 % for the secondary level.

What Taiwan Learned from TEDS-M on Teaching Knowledge

As a participating country in TEDS-M, Taiwan intended to examine how future teachers performed and what the weaknesses and strengths of teachers were on teaching knowledge as compared to other countries. The results of MCK and MPCK achievement for future teachers, especially at the primary level, challenged the expectations of Taiwanese scholars in two areas. First, Taiwan ranked number one in performance. Second, Taiwan's percentages of correct answers for some primary items with low-level of difficulty were low.

In Taiwan, future teachers are expected to be knowledgeable and to master the concepts and skills on the field they intend to teach. It is expected that at least 80 % (if not 100 %) of future teachers should provide correct answers for any item at their teaching level. However, Taiwan's data showed that, in the lower secondary-level study, 30 % of MCK and 33 % of MPCK items did not meet the desired 80 % threshold. For the primary-level study, 36 % of MCK and 83 % of MPCK items did not achieve the 80 % threshold. For the type of *thought-oriented mathematical competence* primary-level items,[5] a high rate of 70 % of items did not reach the 80 % threshold. These results are a strong warning for the Taiwanese teacher education system.

---

[4] People may attend many screenings, so the actual rates of people who pass the screenings should be higher than these data.

[5] This is a type of MCK that contrasts with another MCK-type: content-oriented mathematical competence. For more information concerning this section, see the relevant article by Hsieh et al. (2012b).

Why Taiwan Performed Well

The Taiwan TEDS-M team was interested in analyzing how Taiwanese future teachers performed for MCK items with respect to different curricular levels. For this analysis, TEDS-M knowledge items were classified according to four curricular levels: primary, lower secondary, upper secondary or tertiary. The results showed that, in comparison to all participating countries, Taiwan demonstrated a unique pattern in the lower secondary-level study. As shown in Fig. 2, the pattern exhibited in Taiwan was high achievement with respect to the percentage of correct answers for items from primary, lower secondary, and upper secondary levels, but a sharp decline in percent correct on the tertiary level items. Singapore, which demonstrated performance similar to Taiwan for TIMSS, showed MCK achievement patterns different from those for Taiwan. Singapore, Germany, and Switzerland did not show achievement on primary-level MCK items as high as Taiwan but did show a sharp decline from primary to upper secondary levels. For all other countries (except for Taiwan, Singapore, Germany, and Switzerland), MCK achievement remained approximately the same from secondary to tertiary levels. Since Taiwanese lower secondary-level teacher education programs emphasize mostly tertiary-level mathematics (but do not cover primary-level mathematics), these data show that one of the reasons Taiwan performed better in MCK is that it recruits high-achieving students for secondary teacher education programs.

This idea also explains why Taiwan performed well in MPCK for the lower secondary-level study. Mathematical concepts applied for almost all MPCK items appear in the lower secondary-level, a level in which Taiwan excelled.

For the primary-level study, future Taiwanese teachers achieved high results for primary-level MCK items, lower secondary- and upper secondary-level items (see Fig. 3).

This result may demonstrate that Taiwan recruits high-achieving students for primary teacher education programs. However, a question remains as to why

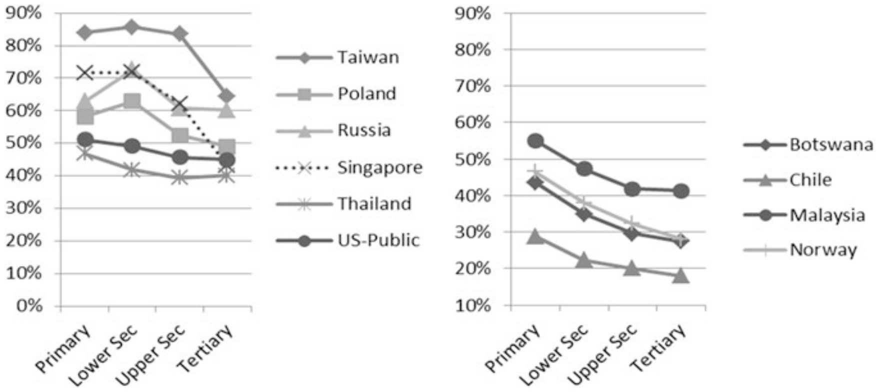


Fig. 2 Percentage of correct answers for MCK items across different levels in the lower secondary-level study for certain countries

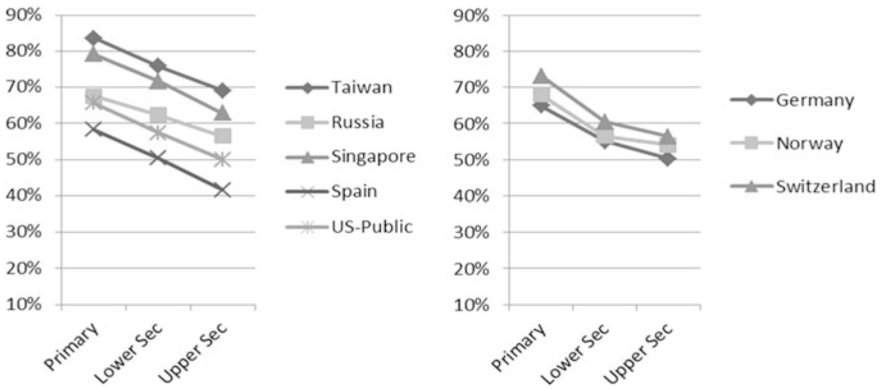


Fig. 3 Percentage of correct answers for MCK items across different levels in the primary-level study for certain countries

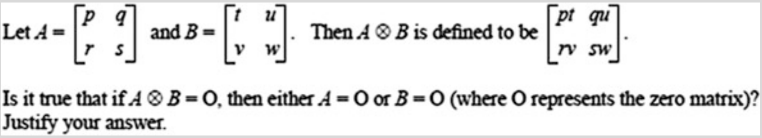
Singapore, which performed worse on the MCK than Taiwan, achieved results similar to Taiwan for the MPCK test. Further research is required to examine factors influencing relevant knowledge achievements.

Other TEDS-M data show that Taiwan may have demonstrated superior performance, especially in the lower secondary-level, because of the following reasons: Taiwan teaches more topics in both school- and tertiary-level mathematics than other countries, and future Taiwanese teachers have increased opportunities to perform challenging problems (thought-oriented). This finding is consistent with findings from analyses of relationships between Opportunity to Learn (OTL), MCK, and MPCK (Hsieh et al. 2012a).

Short activities related to single-item performance

The following questions were posed to the audience.

Example 1: (a lower secondary-level item)



Let $A = \begin{bmatrix} p & q \\ r & s \end{bmatrix}$ and $B = \begin{bmatrix} t & u \\ v & w \end{bmatrix}$. Then $A \otimes B$ is defined to be $\begin{bmatrix} pt & qu \\ rv & sw \end{bmatrix}$.

Is it true that if $A \otimes B = O$, then either $A = O$ or $B = O$ (where O represents the zero matrix)? Justify your answer.

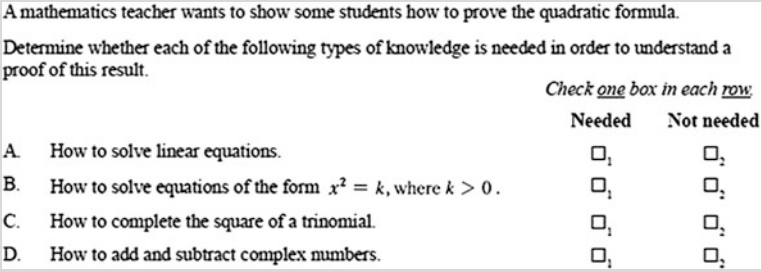
The operation defined in Example 1, MFC814,[6] a tertiary-level MCK item, is not taught in relevant courses. To correctly answer this problem, a test-taker must observe the relationships between mathematical objects, devise formal or informal mathematical arguments, and transform heuristic arguments into valid proofs.

---

[6] The *Knowledge of Algebra for Teaching* (KAT) project, Michigan State University, is acknowledged for item MFC814.

Question 1: What percentage of future mathematics teachers at the secondary level can answer this item correctly in your country?

Example 2: (a lower secondary-level item)



A mathematics teacher wants to show some students how to prove the quadratic formula.

Determine whether each of the following types of knowledge is needed in order to understand a proof of this result.

Check one box in each row.

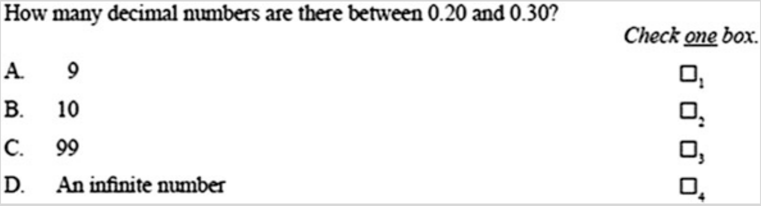
		Needed	Not needed
A.	How to solve linear equations.	☐$_1$	☐$_2$
B.	How to solve equations of the form $x^2 = k$, where $k > 0$.	☐$_1$	☐$_2$
C.	How to complete the square of a trinomial.	☐$_1$	☐$_2$
D.	How to add and subtract complex numbers.	☐$_1$	☐$_2$

Example 2, MFC712, is an MPCK item concerning a formal approach for teaching the quadratic formula. Option C is considered necessary to understanding a proof of the formula.

Question 2: In which of the following situations will future teachers in your country know that option C is necessary? Answer Yes or No to each.

- If they know how to prove the quadratic formula and attempt to prove it when answering this item.
- If they know the pre-requisites for learning how to prove the quadratic formula.
- If they have watched a teacher teaching approaches for proving the quadratic formula.
- If they have had experience teaching how to prove the quadratic formula.
- If they have been taught by faculty in their teacher education programs how to demonstrate the quadratic formula.

Example 3: (a primary-level item)



How many decimal numbers are there between 0.20 and 0.30?

Check one box.

A.	9	☐$_1$
B.	10	☐$_2$
C.	99	☐$_3$
D.	An infinite number	☐$_4$

A special feature of Example 3, MFC304,[7] is that 0.2 is expressed as 0.20.

Question 3: At what grade do teachers teach the addition of decimals with three digits in your country?

---

[7] Item MFC304 is one of a pool of items developed for TEDS-M by Doug Clarke, Peter Sullivan, Kaye Stacey, Ann Roche, and Ray Peck, Melbourne, Australia.

Discussion of other MCK and MPCK items can be found in an article by Hsieh et al. (2012b).

Views from Audience Representatives

After a short exchange with the audience, the chair asked two Audience representatives to "describe any interventions that have been undertaken in Chile and Norway as a consequence of disappointing TEDS-M results."

Liv Sissel Gronmo (Norway) stressed that although there was disappointment with the results, there have been few interventions so far. In particular, concerning the problem that future teachers do not have the necessary competence in mathematics, no measures have been taken so far. On the contrary, a recent change in teacher education has expanded the amount of general pedagogy which seems to be a step in the wrong direction.

María Leonor Varas (Chile) reported that TEDS-M results had—after a first shock—a distinguishable impact in Chile at different levels. For example, it accelerated decisions and deepened interventions that were in the process of implementation (e.g., outcome standards for teacher preparation programs and entrance examinations for teachers). It also led to an increased engagement of mathematicians in teacher preparation in collaboration with mathematics educators (e.g., jointly developing standards for teacher preparation as well as preparing books and materials to support its implementation).

Research in Teacher Education and TEDS-M: International Findings and Implications for Future Policy Research

Research has begun to advance our understanding of the knowledge considered most important for school mathematics teaching (e.g., Baumert et al. 2010; Hill et al. 2007; Schmidt et al. 2011; Tatto 2008; Tatto et al. 2010). For more than a decade, recommendations from relevant societies and expert groups have emphasized that future teachers of school mathematics need to develop a deep understanding of the mathematics they will teach (Conference Board of Mathematical Sciences 2001), and that to be successful "… mathematics teachers need preparation that covers knowledge of mathematics, of how students learn mathematics and of mathematical pedagogy" (National Research Council 2010, p. 123; Education Committee of the EMS 2012). Importantly for our discussion today are calls to collect "… quantitative and qualitative data about the programs of study in mathematics offered and required at teacher preparation institutions … to improve understanding of what sorts of preparation approaches are most effective at developing effective teachers" (National Research Council 2010, p. 124). In this session, we will present some of the challenges involved in doing research in teacher education, the main findings that are emerging from the study, and plans for future research including a new study of novice mathematics teachers.

To recap, the overall goal of TEDS-M was to study in a group of countries how primary and secondary school mathematics teachers learn to teach subject matter content effectively to a wide variety of students as a result of their preparation programs. This comparative approach to exploring teacher education and its influence cross-nationally helped us to understand the combination of teacher education policies, learning opportunities, and levels of mathematics knowledge that future teachers reach in those countries where pupils show high mathematics achievement vis-à-vis those who do not. As we have said in previous articles, the intent of TEDS-M is to replace myths about when, what, and how teachers learn, with facts and conclusions backed by rigorous research (Tatto et al. 2011).

Methods

The most important challenges we encountered were methodological such as the sampling, the instrument development, and, given the diversity of programs we encountered, the approaches to describe the results. TEDS-M used comparative and survey research methods to produce correlational analyses. Original data were collected through the examination of policy documents; assessments of mathematics teaching knowledge; and questionnaires. TEDS-M implemented a two-stage sampling design: (a) selected samples representative of the national population of institutions offering initial teacher education to the target populations; (b) all programs in those institutions were included in the survey; (c) within institutions (and programs), samples of educators and of future teachers were surveyed. Samples had to reach the rigorous IEA sampling standards. Sampling errors were computed using balanced half-sample repeated replication (Fay 1989; Lohr 1999; McCarthy 1966; Tatto et al. 2012). The development of anchor points to interpret the knowledge scores in a meaningful way represented both a challenge and an important step forward in teacher education research. Anchor points can assist teacher preparation programs worldwide to establish benchmarks of performance for their graduates using TEDS-M assessments and analyses. These assessment tools were developed collaboratively and represent meaningful international standards (Tatto et al. 2012).

Data Sources

Policy and context data were collected using country reports, questionnaires, and interviews. TEDS-M conducted (a) surveys of the teacher education institutions using an institutional program questionnaire; (b) surveys of educators and mentors of future teachers in the institutions using a teacher educator questionnaire; and (c) surveys of future teachers in the sampled institutions. Questions on future teacher knowledge of mathematics and mathematics pedagogy were investigated via assessments developed for that purpose.

Results

The results of our study are presented in detail in the TEDS-M international report: Policy, Practice, and Readiness to Teach Primary and Secondary Mathematics in 17 Countries (Tatto et al. 2012), which is available for download from the TEDS-M webpage http://teds.educ.msu.edu/, or from the IEA webpage at http://www.iea.nl3.

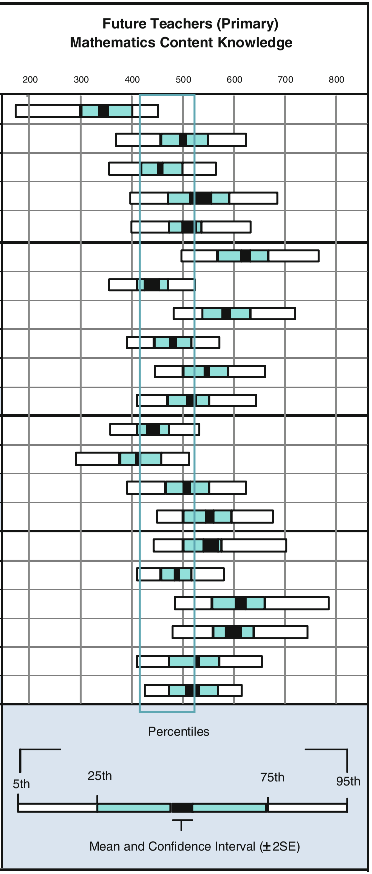
For this presentation, we will only briefly highlight the key international findings from the mathematics knowledge assessments at the primary and lower secondary levels and discuss patterns in the organization of teacher preparation programs that indicate promising directions for policy.

Tables 2 and 3 show the descriptive statistics for mathematics content knowledge (MCK), by program group for the future teachers participating in the study at the primary and lower secondary levels. The tables show a key analysis strategy employed in TEDS-M: that is the way results were presented by "program groups" in order to cater for the different structures of teacher education systems. Table 2 reveals the variation in MCK scores across and within program groups. Given the international mean set at 500 and the standard deviation at 100 it can be seen that the difference in mean MCK scores between some countries, even in the same program group, was between one and two standard deviations. Here it will be helpful to illustrate the use of the anchor points—see above—to interpret TEDS-M results. In the high-scoring countries within each program group, the majority of future teachers had scores at or above the higher MCK anchor point. Differences between countries within program groups tended to be larger among the secondary groups (Table 3) than among the primary groups (Table 2). The results in the United States of America illustrate these differences.

Table 2 shows that in the USA more than 90 % of future primary teachers reach Anchor Point 1, but only 50 % reach Anchor Point 2, whether generalists or specialists; this places the USA below Taiwan, Singapore, and Switzerland in Group 2: primary generalists, and well below Poland, Singapore, Germany, and Thailand in Group 4: primary specialists. Table 3 shows the results of the secondary groups. Close to 70 % of the USA teachers do not even reach Anchor Point 1 in Group 5: lower secondary teachers preparing to teach to Grade 10, placing them below Singapore, Switzerland, Poland, Germany, and Norway. USA future teachers, however, do better in the program Group 6: lower and upper secondary teachers prepared to teach Grade 11 and above in reaching Anchor Point 1, yet they still score well below the future teachers from Taiwan, Singapore, Germany, and the Russian Federation. While in all of these other countries more than 60 % of future teachers reach Anchor Point 2, more than 55 % of USA future teachers fail to reach the same benchmark.

Table 2 Descriptive statistics for mathematics content knowledge, by program group (future teacher, primary level) *Source* Tatto et al. (2012)

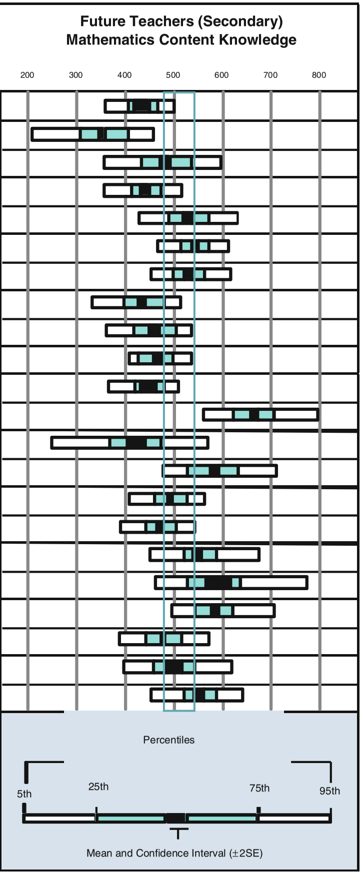
Program Group	Country	Sample Size	Valid Data (N)	Percent Missing (Weighted)	Percent at or above Anchor Point 1 (SE)	Percent at or above Anchor Point 2 (SE)	Scaled Score: Mean (SE)
Group 1. Lower Primary (Grade 4 Maximum)	Georgia	506	506	0.0	11.9 (1.4)	0.9 (0.5)	345 (4)
	Germany	935	907	2.4	86.4 (1.3)	43.9 (2.1)	501 (3)
	Poland[a]	1812	1799	0.9	67.9 (1.3)	16.8 (1.2)	456 (2)
	Russian Federation[b]	2266	2260	0.2	89.7 (2.3)	57.3 (4.6)	536 (10)
	Switzerland[c]	121	121	0.0	90.5 (2.7)	44.2 (5.4)	512 (6)
Group 2. Primary (Grade 6 Maximum)	Chinese Taipei	923	923	0.0	99.4 (0.3)	93.2 (1.4)	623 (4)
	Philippines	592	592	0.0	60.7 (5.1)	6.3 (0.9)	440 (8)
	Singapore	263	262	0.4	100.0	82.5 (2.3)	586 (4)
	Spain	1093	1093	0.0	83.4 (1.6)	26.2 (1.6)	481 (3)
	Switzerland	815	815	0.0	97.2 (0.6)	70.6 (1.4)	548 (2)
	† USA[d]	1310	951	28.6	92.9 (1.2)	50.0 (3.2)	518 (5)
Group 3. Primary / Secondary (Grade 10 Maximum)	Botswana[e]	86	86	0.0	60.6 (5.3)	7.1 (2.8)	441 (6)
	Chile [f]	657	654	0.4	39.5 (1.8)	4.0 (0.7)	413 (2)
	Norway (ALU) [g]	392	392	0.0	88.5 (1.5)	46.9 (2.3)	509 (3)
	Norway (ALU+) [g]	159	159	0.0	96.5 (1.4)	68.7 (3.1)	553 (4)
Group 4. Primary Specialists	Germany	97	97	0.0	96.0 (2.1)	71.7 (7.0)	555 (8)
	Malaysia	576	574	0.4	88.7 (1.1)	28.1 (1.3)	488 (2)
	Poland [a]	300	300	0.0	97.9 (1.0)	91.0 (1.6)	614 (5)
	Singapore	117	117	0.0	98.3 (1.2)	87.3 (2.8)	600 (8)
	Thailand	660	660	0.0	91.7 (0.9)	56.2 (1.4)	528 (2)
	† USA [d]	191	132	33.2	94.9 (1.7)	48.1 (6.5)	520 (7)



1. This table and chart must be read with awareness of the annotations listed earlier.
2. The dagger symbol (†) is used to alert readers to situations where data were available from less than 85% of respondents.
3. The shaded areas identify data that, for reasons explained in the annotations, can be compared with data from other countries with caution.
4. The solid vertical lines on the chart show the two Anchor Points (431 and 516).

Table 3 Descriptive statistics for mathematics content knowledge, by program group (future teacher, lower secondary level) *Source* Tatto et al. (2012)

Program Group	Country	Sample Size	Valid Data (N)	Percent Missing (Weighted)	Percent at or above Anchor Point 1 (SE)	Percent at or above Anchor Point 2 (SE)	Scaled Score: Mean (SE)
Group 5. Lower Secondary (to Grade 10 Maximum)	Botswana [a]	34	34	0.0	6.0 (4.2)	0.0	436 (7)
	Chile [b]	746	741	0.6	1.2 (0.4)	0.0	354 (3)
	Germany	408	406	0.3	53.5 (3.4)	12.6 (2.2)	483 (5)
	Philippines	733	733	0.0	14.0 (3.0)	0.2 (0.1)	442 (5)
	Poland [c]	158	158	0.0	75.6 (3.5)	34.7 (3.2)	529 (4)
	Singapore	142	142	0.0	86.9 (3.1)	36.6 (4.3)	544 (4)
	Switzerland [d]	141	141	0.0	79.7 (3.4)	26.7 (3.2)	531 (4)
	Norway (ALU)[e]	356	344	3.9	36.1 (3.7)	2.3 (1.4)	435 (3)
	Norway (ALU +)[e]	151	148	1.9	19.3 (1.6)	0.8 (0.4)	461 (5)
	† USA [f]	169	121	32.7	33.5 (2.2)	2.1 (1.3)	468 (4)
Group 6. Lower & Upper Secondary (to Grade 11 and above)	Botswana a	19	19	0.0	21.1 (7.4)	0.0	449 (8)
	Chinese Taipei	365	365	0.0	98.6 (0.8)	95.6 (1.0)	667 (4)
	Georgia [g]	78	78	0.0	18.2 (4.4)	5.0 (2.6)	424 (9)
	Germany	363	362	0.1	93.4 (1.5)	62.1 (2.9)	585 (4)
	Malaysia	389	388	0.2	57.1 (2.3)	6.9 (0.9)	493 (2)
	Oman	268	268	0.0	37.1 (2.7)	1.8 (0.6)	472 (2)
	Poland	140	139	0.8	85.7 (2.6)	35.7 (2.7)	549 (4)
	Russian Federation[h]	2141	2139	0.1	88.8 (1.7)	61.1 (4.3)	594 (13)
	Singapore	251	251	0.0	97.6 (1.0)	62.9 (2.6)	587 (4)
	Thailand	652	652	0.0	41.0 (1.5)	8.4 (1.1)	479 (2)
	Norway (PPU & Masters)[e]	65	65	0.0	57.8 (7.9)	16.0 (4.6)	503 (8)
	† USA [f]	438	354.0	21.3	87.1 (2.0)	44.5 (3.9)	553 (5)



Notes:

1. This table and chart must be read with awareness of the annotations listed earlier.
2. The dagger symbol (†) is used to alert readers to situations where data were available from less than 85% of respondents.
3. The shaded areas identify data that, for reasons explained in the annotations, can be compared with data from other countries with caution.
4. The solid vertical lines on the chart show the two Anchor Points (490 and 559).

What may help explain these results? Our study shows that the design of teacher education programs and curricula content and orientation may have substantial effects on the level of knowledge that future teachers are able to acquire. In general, programs where future teachers are more successful in our assessments have rigorous standards in selecting those who enter the program, they have a demanding and sequential (versus repetitive) university and school mathematics curriculum, frequent formative evaluations (written and oral), and stringent graduation requirements. A conceptual, problem solving, and active learning orientation seems to characterize the views of mathematics among those future teachers who score higher in our assessments, likely reflecting the way they themselves learned mathematics and the views that their programs espouse (Tatto et al. 2012; Tatto et al. in press).

What could be some of the policy implications emerging from TEDS-M? Teacher education programs can increase their effectiveness by selecting future teachers according to their characteristics (e.g., previous school performance) and strengthening formative and summative evaluation as they progress through their program. In fact previous performance in school, gender and socioeconomic status are characteristics that seemed to explain in some degree the knowledge that future teachers demonstrate at the end of their formal initial teacher education (Tatto et al. in press).

A general conclusion of our analysis is that future teachers, who did well in their previous schooling, and specifically in high school, perform better in our mathematics knowledge for teaching assessments (Tatto et al. in press). In all countries, opportunities to learn university level mathematics and mathematics of the school curriculum, and reading research on teaching and mathematics were related to future teachers' knowledge as measured in our assessments. The more traditional view of mathematics as a finished product has given way to a more contemporary view of mathematics as a process of inquiry (Ernest 1989, p. 250), and to the idea that mathematics is better learned through a conceptual and inquiry-based form of learning. In general, successful programs seemed to be more coherently organized around the idea of what effective teachers need to know (Tatto et al. in press).

For primary programs, the most important positive influence of teacher education on mathematics knowledge for teaching is the opportunity to learn school level mathematics, specifically in the areas of function, probability, and calculus (Tatto et al. in press). Another important yet negative association with knowledge as measured by our assessment was found among future teachers who as a group hold the exclusive view that can be summarized as "mathematics is a collection of rules and procedures that prescribe how to solve a problem". This is a view that stands in contrast with the more accepted view, supported by cognitive science research on learning that, "in addition to getting a right answer in mathematics, it is important to understand why the answer is correct" and that in addition to learning basic facts, "teachers should allow pupils to figure out their own ways to solve a mathematical problem." While the first is a view that may be espoused by teacher education programs, it could also be a "naïve view" held by future teachers based on commonly held "cultural norms" and which remains unchallenged and unchanged by their program. In other words, the program may end up reinforcing traditional ways of teaching and learning, already acquired by future teachers in their own schooling (Tatto 1999).

For secondary programs the most important influence on knowledge for teaching is the opportunity to learn university level mathematics, specifically geometry, and the opportunity to read research in teaching and learning (Tatto et al. in press). As in the primary programs the exclusive view that "mathematics is a collection of rules and procedures that prescribe how to solve a problem" had a negative association with performance in our assessment.

One conclusion of this study is that teacher education programs' quality of opportunities to learn—as measured by their association with high levels of mathematics teaching knowledge, coherence on program philosophy and approaches, and internal and external quality assurance and accountability mechanisms, are all features that seem to contribute to increased levels of mathematics knowledge for teaching among future teachers. While the TEDS-M study is limited in how much it can tell us about the effects of high quality teacher education on initial teaching practice, it provides the basis for the development of further inquiry into this unexplored yet essential question: what elements contribute to the development of high quality teachers?

A further study, FIRSTMATH, will attempt to answer this question. This is a study of novice teachers' development of mathematical knowledge for teaching and the influence of previous preparation, school context and opportunities to learn-on-the-job, on that knowledge. FIRSTMATH will explore the connections between initial teacher education and what is learned on the job as it concerns knowledge, skills, and curricular content; and the degree to which standards, accountability, and other similar mechanisms operate to regulate the support that beginning teachers of mathematics receive during their first years of teaching. For more information on TEDS-M and FIRSTMATH consult the following websites: http://teds.educ.msu.edu/ and http://firstmath.educ.msu.edu/.

Views from Audience Representatives

Finally, the chair asked two Audience representatives their view on "how mathematics (teacher) educators in their country value TEDS-M as a contribution to research."

Mellony Graven (South Africa) highlighted that her country did not participate in TEDS-M (but did in the preceding MT21 study), partially for cost reasons. In South Africa, many teacher educators are unaware of the study, and the local literature on mathematics (teacher) education shows little take up or mention of the study.

Deborah Loewenberg Ball (USA) stressed the importance of TEDS-M: it has advanced the international conversation about what it means to be mathematically well-prepared for teaching, it has raised questions about the degree to which common measures of mathematical knowledge for teaching can be developed, and it has made possible more common research about selection, education, and effects on initial teaching across countries.

The Panel closed with concluding words by the Panel members, expressing thanks to the IPC including the Panel-liaison *Gabriele Kaiser* (Germany) and the local organizers including *Mi-Kyung Ju* (South Korea) as the presider of the Panel.

References

Adler, J., Ball, D. L., Krainer, K., Lin, F.-L., & Novotna, J. (2005). Mirror images of an emerging field: Researching mathematics teacher education. *Educational Studies in Mathematics, 60*(3), 359-381.

Anthony, G., & Walshaw, M. (2009). *Effective pedagogy in mathematics: Educational practices series, 19. International Academy of Education*, International Bureau of Education & UNESCO. Available online from the UNESCO website.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M., & Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal, 47*(1), 133-180.

Blömeke, S. (2011). WYSIWYG: Von nicht erfüllten Erwartungen und übererfüllten Hoffnungen – Organisationsstrukturen der Lehrerbildung aus internationaler Perspektive. *Erziehungswissenschaft, 43*, 13-31.

Blömeke, S., Kaiser, G., Lehmann, R., & Schmidt, W. H. (2008). Introduction to the issue on empirical research on mathematics teachers and their education. *ZDM – The International Journal on Mathematics Education, 40*(5), 715-717.

Conference Board of Mathematical Sciences (2001). *The mathematical education of teachers (Vol. 2).* Washington, DC: American Mathematical Society.

Connelly, F. M., & Clandinin, D. J. (1988). *Teachers as curriculum planners: Narratives of experience*. New York, USA: Teachers College Press.

Education Committee of the EMS (2012). It is Necessary that Teachers are Mathematically Proficient, but is it Sufficient? Solid Findings in Mathematics Education on Teacher Knowledge. *Newsletter of the European Mathematical Society, March 2012*, Issue 83, 46-50.

Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. In: Ernest, E. (Ed.), *Mathematics Teaching: The State of the Art* (pp. 249-254). New York, USA: Falmer Press.

Fay, R. E. (1989). Theoretical Application of Weighting for Variance Calculation. *Proceedings of the Section on Survey Research Methods of the American Statistical Association*, 212-217.

Fullan, M. (1993). *Change forces. Probing the depths of educational reform*. London: Falmer Press.

Garden, R., Lie, S., Robitaille, D. F., Angell, C., Martin, M. O., Mullis, I. V. S., et al. (2006). *TIMSS Advanced 2008 assessment frameworks*. Chestnut Hill, MA: Boston College.

Hattie, J. A. (2003). *Teachers make a difference: What is the research evidence?* Australian Council for Educational Research Annual Conference on: Building Teacher Quality.

Hill, H. C., Rowan, B., & Ball, D. L. (2005). Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement. *American Educational Research Journal, 42*(2), 371-406.

Hill, H. C., Sleep, L., Lewis, J. M., & Ball, D. L. (2007). Assessing teachers' mathematical knowledge: What matters and what evidence counts? In F. K. Lester (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning* (pp. 111-156). Charlotte, NC: Information Age.

Hsieh, F.-J., Lin, P.-J., & Shy, H.-Y. (2012a). Mathematics teacher education in Taiwan. In Tso, T. Y. (Ed.), *Proc. 36th Conf. of the Int. Group for the Psychology of Mathematics Education, Vol. 1* (pp. 187-206). Taipei, Taiwan: PME.

Hsieh, F.-J., Lin, P.-J., & Wang, T.-Y. (2012b). Mathematics related teaching competence of Taiwanese Primary Future Teachers: Evidence from the TEDS-M. *ZDM – The International Journal on Mathematics Education*. DOI: 10.1007/s11858-011-0377-7 http://www.springerlink.com/content/074647770n574812/fulltext.pdf.

Huckstep, P., Rowland, T., & Thwaites, A. (2003). Primary teachers' mathematics content knowledge: what does it look like in the classroom? *Education-line database*. Accessed 1 April 2012 < http://www.leeds.ac.uk/educol/documents/00002534.htm>

Krainer, K. (2011). Teachers as stakeholders in mathematics education research. In B. Ubuz (Ed.), *Proc. 35th Conf. of the Int. Group for the Psychology of Mathematics Education, Volume 1* (pp. 47-62). Ankara, Turkey: Middle East Technical University.

Loewenberg-Ball, D., Blömeke, S., Delaney, S., & Kaiser, G. (Eds.) (2012). Measuring teacher knowledge - approaches and results from a cross-national perspective. *ZDM - The International Journal on Mathematics Education, 44*(2). (See http://www.springer.com/education+%26+language/mathematics+education/journal/11858).

Lohr, L. S. (1999). *Sampling: Design and Analysis*. Pacific Grove, CA: Duxbury Press.

McCarthy, P. J. (1966). Replication: An Approach to the Analysis of Data from Complex Surveys. *Vital and Health Statistics, Series 2, No. 14*. Hyattsville, MD: National Center for Health Statistics.

Mullis, I. V. S., Martin, M. O., Ruddock, G. J., O'Sullivan, C. Y., Arora, A., & Erberber, E. (2005). *TIMSS 2007 Assessment Frameworks*. Chestnut Hill, MA: Boston College.

National Research Council (2010). *Preparing teachers: Building evidence for sound policy (Committee on the Study of Teacher Preparation Programs in the United States, Division of Behavioral and Social Sciences and Education)*. Washington, DC: National Academy Press.

Schmidt, W., Blömeke, S., & Tatto, M. T. (2011). *Teacher education matters. A study of middle school mathematics teacher preparation in six countries*. New York, NY: Teachers College Press.

Senk, S. L., Tatto, M. T., Reckase, M., Rowley, G., Peck, R., & Bankov, K. (2012). Knowledge of future primary teachers for teaching mathematics: An international comparative study, *ZDM – The International Journal on Mathematics Education*. DOI: 10.1007/s11858-012-0400-7 http://www.springerlink.com/content/f881483261201gu4/

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(3), 4-14.

Tatto, M. T. (2008). Teacher policy: A framework for comparative analysis. *Prospects: Quarterly Review of Comparative Education, 38*, 487-508.

Tatto, M. T. (1999). The socializing influence of normative cohesive teacher education on teachers' beliefs about instructional choice. *Teachers and Teaching, 5*, 111-134.

Tatto, M. T. (Ed.) (2013, published in 2014). *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, The Netherlands: International Association for the Evaluation of Student Achievement.

Tatto, M.T., Lerman, S., & Novotná, J. (2010). The organization of the mathematics preparation and development of teachers: A report from the ICMI Study 15. *Journal of Mathematics Teacher Education, 13*, 313-324.

Tatto, M. T., Rodriguez, M. C., & Lu, Y. (in press). *The Influence of Teacher Education on Mathematics Teaching Knowledge: Local Implementation of Global Ideals*. In G. K. LeTendre & A. W. Wiseman (Eds.), Promoting and Sustaining a Quality Teacher Workforce Worldwide. Bingley, United Kingdom: Emerald.

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, The Netherlands: International Association for the Evaluation of Student Achievement.

Tatto, M. T., & Senk, S., Rowley, G., & Peck, R. (2011). The Mathematics Education of Future Primary and Secondary Teachers: Methods and findings from the Teacher Education and Development Study in Mathematics. *Journal of Teacher Education, 62*(2), 121-137.

Wu, M. L., Adams, R. J., Wilson, M. R., & Haldane, S. A. (2007). *ACER ConQuest Version 2: Generalised item response modelling software [computer program].* Camberwell, Victoria: Australian Council for Educational Research.

Mathematics Education in East Asia

Frederick K.S. Leung, Kyungmee Park, Yoshinori Shimizu and Binyan Xu

Abstract Students in East Asia have been performing extremely well in international studies of mathematics achievements such as TIMSS and PISA. On the other hand, education practices in East Asian countries look different from Western practices, and some practices look very backward and contradictory to what are considered as good practices. Given these intriguing phenomena, this plenary panel aims to discuss different aspects of mathematics education in these East Asian countries, and illustrate its salient features with examples. These aspects include classroom teaching in regular schools and tutorial schools, and pre-service and in-service teacher education and development. The reasons behind the distinctive features of mathematics education in East Asia are then explored, and it is argued that the common Confucian Heritage Culture (CHC) that these countries share best explain these features. This panel presentation is not meant to promote the superior student achievement or good educational practices in East Asia. Rather, it highlights the cultural differences between CHC and Western cultures, rather than the superiority of one over the other. A cultural explanation also means that simple transplant of educational policies and practices from one culture to another will not work. The panel points to the important role culture plays in accounting for educational practices and student achievement.

F.K.S. Leung (✉)
The University of Hong Kong, Pokfulam, Hong Kong
e-mail: frederickleung@hku.hk

K. Park
Hongik University, Seoul, South Korea
e-mail: kpark@hongik.ac.kr

Y. Shimizu
University of Tsukuba, Tsukuba, Japan
e-mail: yshimizu@human.tsukuba.ac.jp

B. Xu
East China Normal University, Shanghai, China
e-mail: xubinyan650@hotmail.com

S.J. Cho (ed.), *The Proceedings of the 12th International Congress on Mathematical Education*, DOI 10.1007/978-3-319-12688-3_11

Introduction

Students in East Asia have been performing extremely well in international studies of mathematics achievements such as TIMSS and PISA (Beaton et al. 1996; Mullis et al. 1997, 2000, 2004, 2008, 2012; OECD 2001, 2003, 2004, 2010). On the other hand, classroom studies show that mathematics teaching in these countries is rather backward and traditional. International studies on teacher education and development also show that practices in East Asian countries are markedly different from those in "western" countries. Furthermore, comparative studies in teacher knowledge seem to suggest that mathematics teachers in East Asia have more solid understanding of the subject matter as well.

Given these intriguing phenomena, this plenary panel aims to present the current picture of different aspects of mathematics education in these East Asian countries more vividly, and to explore into the reasons behind these distinctive features of mathematics education. In this panel presentation, East Asia is a cultural rather than geographic demarcation. East Asian "countries" refer to systems or economies that are under the influence of the Confucian Heritage Culture, or CHC in short. They include China, Hong Kong, Japan, Korea, Singapore, and Taiwan. The classroom practices, teacher education and development, as well as the educational and socio-cultural contexts in these East Asian countries will be discussed and illustrated with examples.

Classroom Teaching in East Asia

Classroom Teaching in Regular Schools

There have been many studies about the features of mathematics classroom teaching in East Asia. For example, Zhang et al. (2004) stated that the most coherent and visible principle for mathematics instruction in China is emphasizing the importance of foundations, and the principle of "basic knowledge and basic skills" was explicitly put forward for the teaching of mathematics. Gu et al. (2004) claimed that teaching with variation is a Chinese way of promoting effective mathematics learning. According to Gu et al. (2004) which was based on a series of longitudinal mathematics teaching experiments in China, meaningful learning enables learners to establish a substantial and non-arbitrary connection between their new knowledge and previous knowledge. Classroom activities can be developed to help students establish this kind of connection by experiencing certain dimensions of variation. The theory suggests that two types of variation are helpful for meaningful learning, "conceptual variation" and "procedural variation" (Gu et al. 2004).

A number of comparative studies of classroom teaching in East Asian countries and western countries have been conducted, and among them Leung's study provided the most comprehensive interpretation of mathematics teaching in East Asia. In an attempt to search for an East Asian identify in mathematics education, Leung (2001) characterized the salient features of classroom teaching in East Asia and those in the West. He presented six dichotomies of teaching and learning: product (content) versus process; rote learning versus meaningful learning; studying hard versus pleasurable learning; extrinsic versus intrinsic motivation; whole class teaching versus individualized learning; and competence of teachers: subject matter versus pedagogy. Among the six dichotomies, product (content) versus process and whole class teaching versus individualized learning capture best the essence of the differences in mathematics teaching between East Asia and the West.

Two lesson videos were analyzed and discussed in the plenary panel session. As a representative East Asian lesson, an 11th grade Chinese lesson in Shanghai dealing with trigonometric ratio was chosen. In this review lesson, the teacher arranged the mathematics content on trigonometric ratio according to the structure of the knowledge which had already been dealt with in the class, and students accepted and internalized the knowledge structure and reflected on their own understanding. The Chinese lesson shows heavy dependence on teacher's explanation, and the teacher emphasized acquiring mathematics knowledge. Mathematics teaching was analogous to getting the body of knowledge across from the teacher to the students.

For the Western lesson, an 8th grade US lesson in San Diego dealing with linear function was chosen as a representative one. This lesson was characterized as a 'guided development lesson' by the local researchers. The lesson started with some individual activities on exploring the characteristics of functions, and then the teacher invited a student to share his opinion with his classmates. Students were given ample activities and investigations. This lesson seems to support the contemporary Western view that the critical attribute of mathematics is its distinctive way or process of dealing with reality. This process gives rise to a body of knowledge, which is also worthwhile subject matter for study. Since the critical attribute is the process, it is more important to get hold of the process rather than the content arising out of the process.

The Chinese lesson is affirming the importance of the teacher and the subject matter, while student-centered education is the basic tenor in the US lesson. We are not implying that all East Asian countries are on one side of the dichotomies and all western countries are on the other side. In fact, it is a matter of the relative positions of the two cultures on a continuum rather than two incompatible standpoints.

Teaching in Tutorial Schools

It is well known that there are various types of tutorial schools outside the formal educational system in East Asia. These tutorial schools provide supplementary help in academic subjects both for following-up what is taught in regular schools and for preparing for entrance examinations to the next school levels. The content of the

Table 1 Expenditure for private tutoring (2012 data taken from Asian Developmental Bank)

Country	Total expenditure for private tutoring (billion)
Hong Kong	US$0.255
Singapore	US$0.682
Japan	US$12.1
Korea	US$17.3

courses in those schools can be remedial or accelerated. Tutorial schools range from two or three students meeting in the home of a teacher to hundreds of students in dozens of classes in campuses all over the country.

A huge amount of money is involved in private tutoring. The expenditure for some countries in East Asia is shown in Table 1.

There are both advantages and drawbacks in having such institutions. First, tutorial schools help students to learn, and thus extend their human capital which can in turn contribute to economic development. On the other hand, tutorial schools usually maintain or exacerbate social and economic inequalities. Also, tutorial schools may dominate students' lives and restrict their leisure time in ways that are psychologically and educationally undesirable.

Tutorial Schools or Private Tutoring in Japan

Table 2 shows the percentages of Japanese students in grades 6 and 9 who attended tutorial (*Juku*) schools, including lessons with private tutors (Ministry of Education, Science, Sports, and Culture, 2010). Roughly half of grade 6 students attended some form of outside school education and more than 62 % of grade 9 students attended tutorials. In reality, there are some differences between the urban areas and small cities or rural areas in students' attendance. In urban areas, there are large *Juku* schools with a competitive atmosphere mostly attended by students preparing for the university entrance examination. On the other hand, many rural *Juku* schools for elementary and junior high schools are more informal, and basically aim to provide immediate improvement of school performance. Besides *Juku* schools

Table 2 Attendance of grade 6 and grade 9 Japanese students in *Juku* schools, including lessons with private tutors (National Institute for Educational Policy Research 2010)

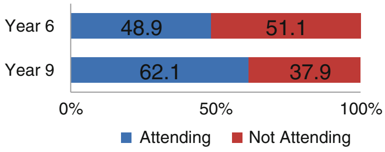


Table 3 Learning in *Juku* schools (National Institute for Educational Policy Research 2010)

Do you study in *Juku* schools (including private tutors)?	6th graders	9th graders
(1) Not attending	52.1	37.9
(2) Learning advanced content or difficult topics	23.5	18.1
(3) Learning the topic taught but not well-understood in schools	7.5	10.0
(4) Both (2) and (3)	8.5	25.9
(5) Others	8.2	7.9

which provide supplementary help in academic subjects, there are enrichment classes on other activities such as swimming, piano, or abacus.

Table 3 shows the various purposes for attending *Juku* schools. As Table 3 shows, in general learning advanced content or difficult topics is the major purpose of the Japanese students' attendance.

Two Japanese tutorial schools were described in the plenary panel session, one mainly for elementary and junior high school students, and the other mainly for senior high school students. They have different courses and systems. The first tutorial school is a *Juku* School in Tsukuba City, and the number of students is roughly 400. The school offers "afterschool classes" in weekday evenings for teaching advanced topics, and they provide a bus service to pick up students. The school runs a "Study Camp" every year during the summer vacation, where students stay in a hotel for a few days and learn together.

The other school belongs to an affiliated group of tutorial schools of more than 120 schools all over the country. The school is for university intended senior high school students who prepare for the entrance examination to universities. It provides students with an ICT-enhanced self-learning system that emphasizes a PDCA (Plan-Do-Check-Action) cycle for learning with immediate feedback. All the lectures are delivered through a Local Area Network. Each student comes to the tutorial school after their regular school class and learns with a computer. The progress of their learning is monitored by the teachers at the school and the students have the opportunities for consulting with the teachers periodically to discuss about their choice of intended university and so on.

Tutorial Schools in Korea

Korea conducts a national survey annually on tutorial schools. Based on the survey done in 2011 with 46,000 students and parents, 50.2 % of elementary and secondary students were participating in mathematics tutorial schools. This rate was the highest among all the subjects.

There are a variety of tutorial schools in Korea according to the achievement levels of the students, their purposes of attending tutorial schools, etc.:

- Repetition of school mathematics content
- Accelerated learning

- Preparing for mathematics contests or the Mathematics Olympiad
- Preparing for entrance examinations of gifted schools

To reduce the country's addiction to private, after-hours tutoring academies (called *hagwons*), the authorities have begun enforcing a curfew to stop children from studying in *hagwons* after 10 p.m. (TIME magazine, 25 Sep 2011).

Teacher Education and Development

"The success of any plan for improving educational outcomes depends on the teachers who carry it out and thus on the abilities of those attracted to the field and their preparation" (National Research Council 2010, p. 1). In East Asia, respecting teachers and attaching importance to education are an unchanging theme and a traditional virtue (Wang 2012). Teachers play the role of a guide, and instruction is teacher dominated and student involvement is minimal (Leung 2001). On the other hand teachers try to understand their students' learning and want their students to be happy in the future, which means that they need to work hard in school (Ferreras et al. 2010). They bear the responsibility if students do not study hard or work well. One of the Chinese idioms illustrates this typical characteristic of teachers in East Asia: Unpolished jade never shines; To teach without severity is the teacher's laziness (玉不琢, 不成器; 教不严, 师之惰).

In the following section, how teacher preparation and development in East Asia are carried out will be presented.

Pre-service Education: How to Become a Mathematics Teacher in East Asia

There are diversities in terms of the mechanism for preparing teachers. Some East Asian systems (such as in Korea or in Mainland China) provide an integrated approach where prospective teachers acquire a teacher certificate through a four-year bachelor degree program at a comprehensive university or teacher education university. Some systems (such as Hong Kong or Japan) adopt an end-on approach where prospective teachers complete a bachelor degree and then take a one- or two-year Post Graduate Certificate in Education program. Notwithstanding these differences, some similar characteristics of pre-service teacher training in teachers colleges and normal universities can be summarized as follows (Li et al. 2008, p. 70):

- Providing prospective teachers with a solid foundation of mathematical knowledge and advanced mathematical literacy;

- Emphasizing the review and study of elementary mathematics. It is believed that a profound understanding of elementary mathematics and strong problem-solving abilities in this field are crucial to becoming a qualified mathematics teacher.

The model in each system has its own strengths and weaknesses with regard to acquiring subject matter knowledge, pedagogical knowledge and teaching skills, but they share similar characteristics. The contents of the mathematics teacher preparation programs in some selected institutions are shown in Table 4.

As can be seen in Table 4, the Korean (minimum 30 %), Chinese (41 %) and Japanese (33 %) programs emphasize the foundations of mathematics knowledge in terms of its systematic structure, and the demand for logical reasoning. These features could reflect the belief that high quality teaching requires that teachers have a deep knowledge of the subject matter. But, the ways such a belief is reflected in practice depend on the specific contexts found in different countries.

Most of the systems require prospective teachers to obtain a government-issued certificate or license signifying that the candidates have completed the required professional preparation. In many systems, candidates also need to take a teacher employment test, and there is an emphasis on subject matter knowledge in this test in different countries.

Table 4 Outline of Teacher preparation courses for secondary mathematics majors by selected institutions

	Mathematics (%) (required and elective) (e.g. Linear algebra, number theory, real analysis, complex analysis, differential geometry, topology, probability and statistics)	Mathematics education (%) (e.g. Methodology of mathematics education, curriculum in mathematics education, problem solving and mathematics competition)	General pedagogy (%) (e.g. Philosophy of educational and history of education, curriculum and evaluation, educational method and technology, educational psychology)	Teaching practicum (%)	General or other courses (%) (e.g. Foreign language, health and sports subjects)
China[1]	41	8	10	12	29
Japan[2]	33	15	16	10	26
Korea[3]	30	6	13	3	48

[1] East China Normal University

[2] Hiroshima University

[3] Specified by the MOE of Korea (minimum units. Most students take more mathematics, mathematics education and general education courses)

Teacher Employment Test (TET) in Korea

In Korea, to be employed by national and public schools, a certified teacher must pass the teacher employment test administered by the 16 Metropolitan and Provincial Offices of Education (Ingersoll 2009, p. 58). The competition rates for mathematics in TET differ from one school district to another, but the average competition rate is higher than 10:1, i.e., more than 10 candidates compete for one place.

In the TET administered by the MOE of Korea, the core subjects are 'mathematics', 'mathematics education', and 'general pedagogy'. To examine whether a prospective teacher has successfully developed the practical competency to teach in the classroom, the TET consists of three stages. Table 5 shows the core subjects in the three stages of the examination.

In the first stage, the TET includes 26 questions about mathematics (52 %), 14 questions about mathematics education (28 %), and 40 questions about general pedagogy (20 %) in the form of multiple choice items. In the second stage, the test

Table 5 The core subjects and three stages of the Korean TET

Area	Contents	Relevant knowledge	Percent		
			Stage 1 (%)	Stage 2 (%)	Stage 3 (%)
Mathematics	Linear algebra Abstract algebra Number theory Real analysis Complex analysis Differential geometry Topology Probability and statistics Discrete mathematics	Content knowledge	52	55–60	0
Mathematics education	Mathematics curriculum and Evaluation, History of mathematics education, Theory of instruction in mathematics, psychology of teaching mathematics	Pedagogical content knowledge	28	35–40	60
General pedagogy	Philosophy of education and history of education, curriculum and evaluation. educational method and technology educational psychology, educational sociology, educational administration and management	General pedagogical knowledge	20	0	40

sets four questions from mathematics (60–65 %) and mathematics education (35–40 %) in the form of essay items; there are no questions about general pedagogy.

In the final stage, the TET assesses candidates by in-depth interview and micro-teaching. In the interview, candidates are given a set of questions related to practical issues involving school teaching such as class management and administration issues. In micro-teaching, candidates are asked to develop a teaching plan for a given mathematical topic. They are required to integrate certain instruction features such as using ICT and collaborative learning into the plan. After they set up their plans, they conduct micro-teaching based on the plans for 20 min. The final decision of teacher selection is based on the cumulative scores through the three stages.

Employment Test in Japan

Due to a decline in the school age population in Japan in recent years, the job opportunities for prospective teachers are limited and only about 30–40 % of graduates of teacher training colleges are able to secure employment in public schools. In principle, mathematics teachers at secondary schools teach only mathematics, whereas teachers at elementary schools teach most subjects. Because of this difference, more courses in pedagogy are required for those intending to teach at the lower grade levels, whereas those intending to teach at the upper grade levels are required to take more mathematics. In addition to the academic course work, teacher-training programs include a practicum (teaching practice). Prospective elementary school teachers are required to spend at least four weeks in a school for teaching practice and those for lower and upper secondary school are required to spend at least two weeks. The practicum is usually preceded and followed by a total of 15–30 h of related guidance and reflections. The national universities for teacher training have affiliated schools for the purpose of teaching practice.

The board of education of each prefecture gives a teacher certificate to a person who has completed the prescribed basic qualifications and credits at the authorized colleges and universities. The competition rates of Teacher Employment differ among school levels and from one school district (prefecture) to another, but the average competition rate was about 6:1 in 2011 (see Table 6).

Table 6 Applicants, employees, and competition rate in 2011 by school levels (*data source* Ministry of Education of Japan, as of 1 June 2011)

School level	Applicants	Those who took the test	Employees	Competition rate
Primary school	63,800	57,817	12,882	4.5
Lower secondary school	71,212	63,125	8,068	7.8
Upper secondary school	42,506	37,629	4,904	7.7

For some prefectures, the average competition rate is more than 10 (Iwate 13.6; Nagasaki 13.3), for others, less than 10 (Tokyo 5.7; Toyama 3.7). Each prefecture prepares and conducts an employment test that is conducted at two phases. The first phase is a paper and pencil test (one day in July), and the test subjects consist of general education, mathematics, and mathematics education. The second phase is an interview and micro-teaching (around October).

Teaching Skills Competition for Prospective Mathematics Teachers in China

In China, the mathematicians in teacher education institutions still value the structure and nature of mathematics, and hope to provide students with a refined and profound mathematics foundation, a broad and concise mathematics background, and further try to help students to master mathematics more easily and properly. And they leave the responsibility of connecting higher mathematics to elementary mathematics and the responsibility of providing high quality mathematics pedagogical knowledge to mathematics educators. Furthermore, enhancing the teaching skills of prospective teachers becomes an important part of the teacher preparation program.

At the end of 1996, the Ministry of Education issued “Suggestions on Teacher Education Reform and Development”, emphasizing curriculum reform in order to face the challenges of the 21st Century. Much importance was attached to the cultivation of scientific thinking and methods, as well as the practical and creative abilities of students, to establish stable bases for teaching practices (Yang et al. 2012, p. 212). Since then different kinds of practice-oriented pre-service programs have been launched and carried out.

Since 2008, the Department of International Cooperation and Exchanges, and the Department of Teacher Education of the Ministry of Education in China, together with Toshiba Company, have been organizing annual competitions on “practice in innovative teaching skills”. Students from normal universities/colleges can participate in this competition, but they should first win the local competitions organized by their universities. Only a few students have the honor to take part in the national competition. This competition includes three parts: a lesson plan (*jiao an*) is designed, the candidates teach a lesson (*mo ni ke*), and after that they should explain the didactical concepts of their lesson (*shuo ke*). Through such competitions, most prospective teachers engage in being trained in teaching skills. Many universities/colleges invite excellent school mathematics teachers to tutor the prospective teachers for these competitions (Fu and Han 2010).

In-service Teacher Education and Development

The success of an education system depends on the appropriate preparation and continuous development of highly qualified teachers. It is widely recognized in East

Asian education communities that learning to teach in the classroom is a life-long process for teachers. As pointed out above, for becoming a mathematics teacher in this region, it is necessary to acquire a teacher certificate for a particular type of schools by completing credits in teacher training courses offered by universities and colleges. Besides these formal systems of teacher preparation, there are other important aspects in the process of mathematics teacher education in East Asia (Leung and Li 2010; Li and Shimizu 2009). In this section, some characteristics of in-service mathematics teacher education and development in East Asia are described.

Stigler and Hiebert (1999) suggested that it is important to examine and learn the ways employed to improve the quality of mathematics classroom instruction in high-achieving education systems in East Asia. A good example is lesson study, which is now familiar to educators around the world. Lesson study is an important practice utilized in Japan to improve the quality of mathematics instruction and to develop teaching competence by promoting collaboration among teachers (Fernandez and Yoshida 2004). There are many other approaches developed and used in the pursuit of excellence in teacher development in different education systems in East Asia. For example, the model of exemplary lesson development is developed and used in mainland China (Huang and Bao 2006). Instructional contests are organized to identify and promote excellent mathematics instruction in several educational systems (e.g., Li and Li 2009; Lin and Li 2009). Master teachers are also an important part of the teaching culture in some education systems in East Asia, and play an important role in nurturing that culture (Li et al. 2008). Some examples of these approaches are provided below.

Lesson Study in Japan

Lesson study, originated in Japan, is a common element in approaches to professional developments whereby a group of teachers collaborate to study the subject matter, instruction, and how students think and understand in the classroom. The original term for lesson study, *jugyo kenkyu* in Japanese, literally means the study of lesson. The origin of lesson study can be traced back to late 1890s, when teachers at elementary schools affiliated to the normal schools started to study lessons by observing and examining them critically (Inagaki 1995). Groups of teachers started to have study meetings on newly proposed teaching methods. The original way of observing and examining lessons has spread nationwide with some major refinements and improvements. The activities of lesson study include planning and implementing the "research lesson" as the core of the whole activity, followed by post-lesson discussion and reflection by participants. A lesson plan plays the key role as a medium for the teachers to share and discuss the ideas to be examined through the process of lesson study.

Lesson study takes place in various contexts (Shimizu 2002). Pre-service teacher-training programs at universities and colleges, for example, include lesson study as a crucial and challenging part in the final week of student teaching practice.

In-service teachers also have opportunities to participate in lesson study. It may be held within their schools, outside their schools but in the same school district, city or prefecture, and even at the national level. Teachers at university-affiliated schools that have a mission to develop a new approach to teaching often open their lesson study for demonstrating an approach or new teaching materials they developed.

Lesson study is a problem solving process whereby a group of teachers work on a problem related to a certain theme. The theme can be related to examining the ways for teaching a new content or for using new teaching materials in relation to the revision of the national curriculum guidelines or to assessing students' learning of a certain difficult topic in mathematics such as common fractions or ratio. The first step of lesson study is defining the problem. In some cases, teachers themselves pose a problem to be solved, such as how to introduce the concept of common fractions, or what is an effective way to motivate students to learn mathematics. Second, planning lesson follows after the problem is defined. A group of teachers collaboratively develop a lesson plan. A lesson plan typically includes analysis of the task to be presented and of the mathematical connections both between the current topic and previous topics (and forthcoming ones in some cases) and within the topic, anticipation of students' approaches to the task, and planning of instructional activities based on them. The third step is a research lesson in which a teacher teaches the planned lesson with observation by colleagues. In most cases, a detailed record of teacher and student utterances is taken by the observers for discussion in a post-lesson meeting. Evaluation of the lesson in the post-lesson meeting focuses on issues such as the role of the implemented tasks, students' responses to the tasks, appropriateness of the teacher's questioning, and so on. Based on the evaluation of the lesson, a revised lesson plan is developed, and the lesson is taught again in another class. These entire process forms a cycle of lesson study.

In lesson study, an outside expert is often invited as an advisor who facilitates and makes comments on the improvement of the lesson in the post-lesson discussion (Fernandez and Yoshida 2004). The expert may be an experienced teacher, a supervisor, a principal of a different school, or a professor from a nearby university. In some cases, the expert is not only invited as a commentator in the discussion on site, the group of teachers may meet with him/her several times prior to conducting the research lesson to discuss issues such as reshaping the objective of the lesson, clarifying the role of the task to be posed in the classroom, anticipating students' responses to the task, and so on. In this context, the outside expert can be a collaborator who shares the responsibility for the quality of the lesson with the teachers, and not just an authority who directs the team of teachers.

After researchers in the U.S. introduced lesson study to the mathematics education community during the late 1990s, the term "lesson study" spread among researchers and educators in the U.S. and later around the world (Lewis 2002). One of the most influential books that discusses about lesson study is *The Teaching Gap* (Stigler and Hiebert 1999). Since then, school teachers in different countries have been trying to implement lesson study in their own education systems. A central question in the "adoption" of the lesson study approach in other places has been raised from the perspective of teaching as a cultural activity.

In the Japanese education system, improvement of teaching and learning through lesson study over a long period of time can take place within a context in which clear learning goals for students are shared among teachers in relation to the national curriculum standards as well as the voluntary hard efforts of the teachers with the support of the administrators. There are challenges to be resolved in practice and research possibilities to be explored in each context.

Teaching Research Groups and Mentorship in China

In the Chinese mainland, almost all mathematics teachers are involved in teaching research activities from the first day of their service, in order to obtain practical knowledge and achieve in-service professional development. This is guaranteed by the policy of "the four-level teaching research network comprising about 100,000 officers" (Yang et al. 2012, p. 216). These officers play an important role in China's education system in managing and guiding school-based teaching research activities on the one hand, and bridging the gap between teaching theories and practice on the other.

The basic units of teaching research network activities are teaching research groups and a mentoring system. They cater to the practical needs and professional development of in-service teachers.

Teaching Research Groups in China

Chinese teachers have a tradition of discussing and reviewing each other's lessons, and gradually it has become a unique culture of opening up one's classroom and discussing one's teaching with others. All the schools in China have teaching research groups, and teachers observing and discussing each other's lessons is commonly guaranteed by the teaching research system. There is more than 50 years' history since a school-based teaching research system was set up in China. In *Secondary School Teaching Research Group Rulebook* (*draft*) issued by MOE in 1957, the study function of the teaching research group was emphasized: "A Teaching Research Group is an organization to research teaching. It is not an administrative department. Its task is to organize teachers to do teaching research in order to improve the quality of education, and not to deal with administrative affairs" (Ministry of Education 1957).

Facing challenges of curriculum reform since the 21st Century, the school-based teaching research system is experiencing changes. The changes result not only from changes in the way of teaching and the way of research, but also from changes in the way of learning and the way of experiencing for teachers. The current essential activities of teaching research groups include:

- Action research on classroom teaching to improve effectiveness, whereby several practical research methods are developed, such as analyzing crucial teaching events (Yang 2009), classroom observation (Huang and Zhang 2011), and so on.

- Development of a distinctive teaching research culture to build up a teacher community through promoting helping each other and inquiring cooperatively (Yao 2010), or to construct a learning environment to promote teachers' professional development in teaching practice through the learning of teaching theories and the analysis of classroom teaching case studies (Gu and Wang 2003).
- Discussion of mathematics contents and corresponding teaching methods to deepen understand and to modify teaching plans [even though this is one of the typical activities, it is facing new challenge because of students' development (Wang 2011)].

Mentoring for Mathematics Teaching in China

Chinese schools have a tradition of arranging for an experienced teacher to be the mentor for a young teacher when the later just begins the teaching career. In this mentoring system, sometimes a new teacher has two mentors: one provides instructions on teaching and another provides guidance on tutoring students. The experienced teacher (mentor) should undertake the responsibility to discuss teaching methods, teaching contents and students' learning styles, etc., with the novice teacher supervised by him/her. The new teacher is expected to observe the mentor's lessons frequently and learn from him/her enthusiastically and humbly. The school encourages new teachers to conduct open lessons regularly and to participate in teaching contests (Yang et al. 2012). The mentor should try to do co-teaching and hold lesson discussion meetings with the mentee, and to suggest alternative teaching practices and ideas (Mao and Yue 2011). In some schools, a ceremony is even held to honor mentors of new teachers and to award them with mentoring certificates.

Mathematics Festival in Korea

The Ministry of Education in Korea provides compulsory in-service teacher training programs, which Korean teachers should take when they are in the 4th or 5th year of teaching. However many teachers are not satisfied with this teacher training program because it is not very relevant to their classroom teaching. Thus mathematics teacher organizations set up their own teacher training program called 'mathematics festival', and this program has been very successful. Mathematics teachers pay the participation fees from their own pocket.

Mathematics festival is a four-day program, and it consists of a variety of lectures and workshops. The lectures mostly combine theory with its application to classroom teaching. Workshops deal with practical teaching ideas including teaching/learning material, manipulatives, teaching tips, etc. Here are examples of lectures and workshops in the 2012 mathematics festival held in January.

- How to teach circumcenter in grade 8
- Harmonics of saxophone from the perspective of mathematics
- Interdisciplinary approach: STEAM (Science, Technology, Engineering, Art, and Mathematics)
- Mathematics magic
- Geogebra, GSP 5.0, Cabri 3D
- Lecture about millennium problems
- Lecture about pentomino with participants' hands-on experience
- Lecture about real world situation (height of shoes)
- Lecture about mathematics and music with musical performance
- Computer session with Geogebra
- Computer session with Cabri 3D
- Hands-on experience to make a traditional 3-dim figure
- Zonodom.

Discussion

As mentioned earlier, this presentation is not meant to show that all East Asian countries are on one side of the extreme and all Western countries are on the other side. But the presentations above do show that there are distinctive features in the classroom teaching and teacher education and development in East Asian countries which are markedly different from the corresponding practices in Western countries. What are the causes of these differences?

Confucian Heritage Culture

There are obviously factors at the personal and institutional levels that have caused the differences. But explanation won't be complete without resorting to factors at the socio-cultural levels. China, Korea, Japan share a common culture, the Confucian Heritage Culture (CHC) (Biggs 1996a). A major characteristic of CHC is the social orientation of its people, in contrast to individual orientation typically found in Western societies. Social Orientation is a "tendency to act in accordance with external expectations or social norms, rather than with internal wishes or personal integrity" (Yang 1981, p. 161). It emphasizes integration and harmony, in contrast to independence and individualism in Western cultures (Taylor 1987, p. 235). People in CHC treasure the community, much more so than the individual. Related characteristics of CHC include compliance, obedience, respect for superiors, and filial piety (孝).

Another more relevant characteristic in the Confucian culture is its emphasis on education, and CHC parents are known to attach great importance to the education and achievement of their children. This rests upon the Confucian presumption that everyone is educable [differences in intelligence… do not inhibit one's educability (Lee 1996, pp. 28–29)] and perfectible ["sagehood is a state that any man can achieve by cumulative effort" (Chai 1965)]. This in turn motivates CHC learners to exercise their effort and will power in their study.

On CHC's emphasis on the community, of course it is the individual who learns, so effective teaching must address the needs of the individual. But too much stress on the individual may exaggerate and aggravate the individual differences that already exist. Also, human beings are social beings, and learning almost always takes place in a social context. Western societies may have gone too far in their attempt to care for the individual, and an optimal emphasis on the individual's role in the community may provide important incentives to learn.

Characteristics of CHC Related to Mathematics Learning

Examination Culture

China is the first country in the world where a national examination system was instituted (Sui Dynasty, A.D. 600). Examinations have always been the route for upward social mobility, and there is a great trust in examination as a fair method of differentiating between the able and the less able. Examination has acquired the status of something of value in itself and becomes an important incentive for studying.

Belief in Effort

In CHC, studying is considered a hardship: one should persevere in order to succeed, and is not supposed to "enjoy" the studying. "Asian parents teach their children early that the route to success lies in hard work" (Stevenson 1987), and this is consistent with the old Chinese saying that "Diligence compensates for stupidity" (以勤补拙). There is a much stronger attribution of success and failure to internal and controllable factors (effort) rather than incontrollable ones (innate ability). This is consistent with the strong belief in effort (or *Gambaru*, which means pushing on, persisting, not giving up) in Japan. Japanese teachers invariably tell parents that "it would be good if the child would just *gambaru* a little more" (White 1987, p. 30).

The Japanese also emphasize on self-discipline (*Kuro*). The idea of self-discipline in Japan is slightly different from that in the West. One should do one's best and keep on struggling, even when being unsuccessful in the end. But this is not a pointless sacrifice. In Japan pushing on, persisting and not giving up are in themselves considered important. The way something is done is more important than the accomplishment in the end.

Stress on Memorization and Practice

Liu (1986) observed the following beliefs in CHC:

> If the purpose is to acquire the knowledge contained in an article, then the best strategy is to memorize the article. … If the purpose is to acquire any new cognitive skill, then the best strategy is to practice repeatedly (Liu 1986, pp. 80–82).

This however does not imply rote learning or rule out creativity. As Biggs observed, "the Chinese believe in skill development first, which typically involves repetitive, as opposed to rote learning, after which there is something to be creative with" (Biggs 1996a, p. 55).

Stress on Reflection

In the Confucian tradition of learning, there is a also strong emphasis on reflection, as the saying "Seeking knowledge without thinking is labour lost; thinking without seeking knowledge is perilous" (学而不思则罔, 思而不学则殆) shows. A true Confucian scholar is one who dedicates himself to studying or seeking knowledge through a lot of practice and memorization. But he also constantly reflects upon what he is practicing and memorizing until he fully grasps the knowledge.

Discussion

Students should enjoy their studies, but they should be taught to rediscover the satisfaction which comes only after hard work. Practice, examination and memorization, when done properly, may each have a place in education. Practice and memorization should not be equated with rote learning, and examination is not a necessary evil. If conducted properly, it provides a good incentive for studying.

The Chinese Language

The Japanese and Korean languages are strongly influenced by the Chinese language. For example, the Japanese language still uses a lot of *Kanji* (Chinese characters). There are features of the Chinese language which are favourable to the learning of mathematics. For example, the Chinese language uses classifiers between every cardinal number and the objects being quantified. This "unscramble the confusion that otherwise surrounds conservation of numbers … explicitness and pragmatic retention of the essential semantic elements in the vocabulary it uses for mathematics" (Brimer and Griffin 1985, p. 23). The regular number system in Chinese also enhances the learning of arithmetic.

As for spoken Chinese, it is a monosyllabic language, where one syllable constitutes one morpheme. In particular, the short pronunciation of the numbers zero to ten makes it easy to process. As Hoosain observed, "the shortest average pronunciation duration of a Chinese number is 265 ms, significantly shorter than the corresponding average of 321 ms in pronouncing a number in English" (Hoosain 1984).

For written Chinese, it is logographic in nature. Chinese words are represented by a large number of different visual symbols known as characters, which are made up of components (radicals), and have an imaginary square as a basic writing unit. Chinese characters put emphasis on the spatial layout of strokes, and the orthography of Chinese is based on the spatial organization of the components of the characters. Lai (2008) pointed out that Chinese characters possess visual properties such as connectivity, closure, linearity and symmetry which are faster and easier to be captured by vision. Studies show that there is a close relationship between the visual-spatial properties of Chinese characters and Chinese people's childhood experience with learning the Chinese orthography. Lai (2008) found that 5 year old Chinese children in Hong Kong, compared to English speaking 5 year olds in Australia, have higher visual perceptual and geometric skills, and higher visual-motor integration skills than motor-reduced visual perceptual skills. Lai used both the motor control theory and the psychogeometric theory of Chinese-character writing to account for the surprising results. It seems that the experience of writing Chinese characters influences one's visual perceptual skills.

Implications

The superior performance of East Asian students in international studies in mathematics naturally prompts one to ask what can be learned from it, especially when one is facing grave problems in mathematics education in the home country. Some education practices in East Asian countries look different from Western practices, and some practices look very backward and contradictory to what are considered as good practices. Biggs (1996b) introduced the term Chinese Learner's Paradox to describe this contradictory phenomenon. But the phenomenon is a paradox only for someone who does not understand the culture. For someone in the culture, education is so important an endeavour that of course students are expected to do well. Compared to students in some other cultures, CHC students work relatively hard, and it is just natural that they do better in these international studies.

This panel presentation is not meant to promote the high achievement of East Asian students, or good educational practices in East Asia, or the superiority of the CHC. It is meant to highlight the cultural differences between CHC and Western cultures, rather than the superiority of one over the other. Theoretically, it hints at the important role culture could play in accounting for educational practices and student achievement. Practically, it provides references for educators in other cultures on education policies and practices. But if culture does impact upon educational practices and student achievement, a cultural explanation also means that simple transplant of educational policies and practices from one culture to another won't work. One can imitate the practices, but cannot transplant the culture, and most practices are effective only in the culture concerned.

Conclusion

In learning from another country, it is important to take any cultural differences that may exist into consideration, and then determine how much can or cannot be learned from another culture. There is a Chinese saying, "Knowing yourself and knowing others, then you will win every battle" (知己知彼, 百战百胜). In learning from another country or region, we should "know others"—not just the student achievement, not just the educational practices, but also the cultural values behind the practices. One should also know oneself—knowing or reflecting upon one's own cultural values. Then one will win any battle in this war of improving mathematics education in one's own country.

References

Beaton, A.E., Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Kelly, D.L. & Smith, T.A. (1996). *Mathematics Achievement in the Middle School Years*. Chestnut Hill, MA: International Study Center, Boston College.

Biggs, J.B. (1996a). Western Misconceptions of the Confucian-Heritage Learning Culture. In D.A. Watkins & J.B. Biggs (eds.). *The Chinese Learner*. Hong Kong: Comparative Education Research Centre: 45-67.

Biggs, J.B. (1996b) Approaches to Learning of Asian Students: A multiple paradox. In J. Pandy, D. Sinha & P.S. Bhawuk (eds.), *Asian Contributions to Cross-Cultural Psychology*. New Delhi : Sage: 180-199.

Brimer, A. & Griffin, P. (1985). *Mathematics Achievement in Hong Kong Secondary Schools*. Hong Kong: Centre of Asian Studies, University of Hong Kong.

Chai, C. (ed. & tr.) (1965). *The Humanist Way in Ancient China: Essential works of Confucianism*. New York: Bantam Books.

Fernandez, C. & Yoshida, M. (2004). *Lesson Study: A Japanese approach to improving mathematics teaching and learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Ferreras, A., Olson, S. & Sztein, E. (2010). *The Teacher Development Continuum in the United States and China: Summary of a Workshop*. U.S. National Commission on Mathematics Instruction. Washington, DC: National Academy Press. http://www.nap.edu/catalog/12874.html

Fu, G.S. & Han, G.F. (2010). A Research on Current Situation and Problems in Normalien Teaching Ability – Teaching ability competition of Normalien as a sample. *Contemporary Teacher Education*, 3,3: 26-30.

Gu, L., Huang, R. & Marton, F. (2004). Teaching with Variation: A Chinese way of promoting effective mathematics learning. In L. Fan, N. Wong, J. Cai, & S. Li (eds.), *How Chinese Learn Mathematics: Perspectives from insiders*. River Edge, NJ: World Scientific Publishing Co.: 309-347.

Gu, L.Y. & Wang, J. (2003). Teachers' Professional Development in Action Education. *Curriculum-Textbook-Pedagogy*, 1-2: 2-10.

Hoosain, R. (1984). Experiments on Digit Spans in the Chinese and English Languages. In Kao, H.S.R. & Hoosain, R. (eds.), *Psychological Studies of the Chinese Language*. Hong Kong: Chinese Language Society of Hong Kong.

Huang, R., & Bao, J. (2006). Towards a Model for Teacher Professional Development in China: Introducing *keli*. *Journal of Mathematics Teacher Education*, 9: 279-298.

Huang, Y.L. & Zhang, M. (2011). Improve the Effectiveness of Mathematics Teaching – Based on the Action Study of Classroom Observation by Research Group. *Journal of Mathematics Education*, 20,3: 67-70.

Inagaki, T. (1995). *A Historical Research on the Theory of Teaching in Meiji-Era* (in Japanese). Tokyo: Hyuuron-Sya.

Ingersoll, R. M. (2009). *A Comparative Study of Teacher Preparation and Qualifications in Six Nations*. The Consortium for Policy Research in Education (CPRE), 58.

Lai, M.Y. (2008). *An Exploratory Study into Chinese and English Speaking Children's Visual Perception*. Ph.D. Thesis, The University of Hong Kong.

Lee, W.O. (1996). The Cultural Context for Chinese Learners: Conceptions of Learning in the Confucian Tradition. In D.A. Watkins & J.B. Biggs, *The Chinese Learner*. Hong Kong: CERC and ACER: 25-41.

Leung, F.K.S. (2001). In Search of an East Asian Identity in Mathematics Education. *Educational Studies in Mathematics*, 47,1: 35-51.

Leung, F.K.S. & Li, Y. (eds.) (2010). *Reforms and Issues in School Mathematics in East Asia: Sharing and understanding mathematics education policies and practices*. Rotterdam: Sense Publishers.

Lewis, C. (2002). *Lesson Study: A handbook of teacher-led instructional change*. Philadelphia: Research for Better Schools.

Li, S.Q., Huang, R.J. & Shin, H. (2008). Discipline Knowledge Preparation for Prospective Secondary Mathematics Teachers: An East Asian Perspective. In: P. Sullivan & T. Wood (eds). *International Handbook of Mathematics Teacher Education: Knowledge and Beliefs in Mathematics Teaching and Teaching Development*. Rotterdam: Sense Publishers: 63-86.

Li, Y., & Li, J. (2009). Mathematics Classroom Instruction Excellence through the Platform of Teaching Contests. *ZDM - The International Journal on Mathematics Education,* 41,3: 263-277.

Li, Y. & Shimizu, Y. (2009). Exemplary Mathematics Instruction and Its Development in Selected Education Systems in East Asia. *ZDM - The International Journal of Mathematics Education*, 41,3: 257–262.

Lin, P. J., & Li, Y. (2009). Searching for Good Mathematics Instruction at Primary School Level Valued in Taiwan. *ZDM - The International Journal on Mathematics Education,* 41,3: 363-378.

Liu, I.M. (1986). Chinese Cognition. In Bond, M.N. (ed.), *The Psychology of the Chinese People*. Hong Kong: Oxford University Press.

Mao, Q.M. & Yue, K. (2011). Dilemma and Solution of Teacher Learning Based on "Apprenticeship". *Research in Educational Development*, 22: 58-62.

Ministry of Education (1957). *Secondary School Teaching Research Group Rulebook (draft).* http://www.ncct.gov.cn/plus/view.php?aid=354 (2013.01.01)

Mullis, I.V.S., Martin, M.O., Beaton, A.E., Gonzalez, E.J., Kelly, D.L. & Smith, T.A. (1997). *Mathematics Achievement in the Primary School Years*. Chestnut Hill, MA: International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., Gregory, K.D., Garden, R.A., O'Connor, K.M., Chrostowski, S.J. & Smith T.A. (2000). *TIMSS 1999 International Mathematics Report*. Chestnut Hill, MA: International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O., Gonzalez, E.J., & Chrostowski, S.J. (2004). *TIMSS 2003 International Mathematics Report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O. & Foy, P. (2008). *TIMSS 2007 International Mathematics Report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Mullis, I.V.S., Martin, M.O., Foy, P. & Arora, A. (2012). *TIMSS 2011 International Results in Mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

National Institute for Educational Policy Research (2010). *Results from 2010 National Assessment of Students' Academic Achievements and Learning Environments*. Tokyo.

National Research Council (2010). *Preparing Teachers: Building Evidence for Sound Policy*. Committee on the Study of Teacher Preparation Programs in the United States. Washington, DC: National Academy Press. http://www.nap.edu/catalog/12882.html

Organisation for Economic Co-operation and Development (2001). *Knowledge and Skills for Life: First Results from PISA 2000*. Paris: OECD Publications.

Organisation for Economic Co-operation and Development (2003). *Literacy Skills for the World of Tomorrow — Further Results from PISA 2000*. Paris: OECD Publications.

Organisation for Economic Co-operation and Development (2004). *Learning for Tomorrow's World – First Results from PISA 2003*, OECD.

Organisation for Economic Co-operation and Development (2010). *PISA 2009 Results: What Students Know and Can Do*, OECD.

Shimizu, Y. (2002). Lesson Study: what, why, and how? In H. Bass, Z.P. Usiskin & G. Burrill (eds.), *Studying Classroom Teaching as a Medium for Professional Development: Proceedings of a U.S.-Japan workshop*. Washington DC: National Academy Press: 53-57, 154-156.

Stevenson, H.W. (1987). America's Math Problems. *Educational Leadership*, 45: 4-10.

Stigler, J.W. & Hiebert, J. (1999). *The Teaching Gap*. New York: Free Press.

Taylor, M. J. (1987). *Chinese Pupils in Britain.* Windsor: NFER-Nelson.

Wang, J.P. (2012). *Mathematics Education in China: Tradition and Reality*. Singapore: Cengage Learning Asia Pte Ltd.

Wang, X.R. (2011). Inquiring and Reflecting Teaching Research Group Activities in Primary and Secondary Schools – A thematic discussion within mathematics teaching research group in one school. *Forum on Education Science*, 4: 32-34.

White, M. (1987). *The Japanese Education Challenge: A commitment to children*. New York: The Free Press.

Yang, K.S. (1981). Social Orientation and Individual Modernity among Chinese Students in Taiwan, *Journal of Social Psychology*, 113: 159-70.

Yang, Y.D. (2009). Capturing the Crucial Incidents in Teaching Research. *People's Education*, 1: 48-49.

Yang, Y.D., Li, J., Gao, H. & Xu, Q.F. (2012). Teacher Education and the Professional Development of Mathematics Teachers. In J.P. Wang, *Mathematics Education in China: Tradition and Reality*. Singapore: Cengage Learning Asia Pte Ltd.: 205-238.

Yao, H. (2010). Teaching Research Activities – Based on constructing teaching research culture. *Primary and Secondary School Management*, 9: 35-36.

Zhang, D., Li, S. & Tang R. (2004). The "Two Basics": Mathematics teaching and learning in mainland China. In L. Fan, N. Wong, J. Cai, & S. Li (eds.), *How Chinese Learn Mathematics: Perspectives from insiders*. River Edge, NJ: World Scientific Publishing Co.: 189-207.

Gender and Mathematics Education Revisited

Gilah C. Leder

Introduction

Beginning in the early 1970s, systematic documentation in many countries of subtle, yet consistent gender differences in mathematics performance and participation in post compulsory mathematics courses in favor of males served as a catalyst for action. In these settings, new legislation and special interventions were introduced to redress demonstrated achievement disparities in mathematics. An important aim of the panel session was to describe the current situation in countries where gender equity is enshrined in legislation at the political level, and, by drawing on recent research and contemporary data gathering tools, to document whether or not inequities have been removed in practice or continue to exist in countries where concern and action about gender differences in mathematics learning have a long standing history.

There are also a significant number of countries where gender and mathematics learning issues have typically been ignored, are still not well recognized by their governments or valued in the wider community. To document the situation in those countries and highlight what progress has been made in those settings were also central aims of the panel's presentation.

The notions of gender parity and gender equality are a unifying thread weaved throughout the presentation. The former is described by UNESCO (2012) as "aim (ing) at achieving equal participation for girls and boys in education", while

> gender equality is understood more broadly as the right to gain access and participate in education, as well as to benefit from gender-sensitive and gender-responsive educational environments and to obtain meaningful education outcomes that ensure that education

---

G.C. Leder (✉)
Monash University, Melbourne, Australia
e-mail: Gilah.Leder@monash.edu

S.J. Cho (ed.), *The Proceedings of the 12th International Congress on Mathematical Education*, DOI 10.1007/978-3-319-12688-3_12

> benefits translate into greater participation in social, economic and political development of their societies. Achieving gender parity is therefore understood as only a first step towards gender equality. (UNESCO 2012, p. 21)

In brief, the areas covered in the session reflected the different perspectives and geographic diversity of the panelists. Attention was given to regions where issues about gender and mathematics education remain barely on the agenda and relatively little is known outside those countries about work and research that have been undertaken. The more widely disseminated research findings and common assumptions about gender and mathematics learning, based on research particularly in Western countries, were also revisited and updated.

The order of presentations was part of our overall message. We therefore started off with presentations from regions where gender and mathematics is not widely seen as a primary issue of concern and/or about which relatively little is known in Western countries—whose research is disseminated widely—and moved to surveys of areas where gender equity is enshrined in legislation at the political level, but in practice inequities continue to exist.

To begin, data referring to India were presented by Jayasree Subramanian. This was followed by Nouzha El Yacoubi whose presentation also covered a large region where concern and progress re-gender and mathematics are still not well known or recognized in the wider research community, and then by Maria Trigueros Gaisman who focused on Mexico. The final three presentations also covered wide geographic areas, in alphabetical order: Australia, Europe, and the United States. Pertinent research and issues were presented respectively by Helen Forgasz, Lovisa Sumpter and Sarah Lubienski.

Each panelist sketched realities, achievements, and outcomes in mathematics education and gender in the area in which she lives and works and of which she has first hand knowledge. Reference was also made to examples of dissonance between theory and practice with respect to mathematics education and gender. Highlighted, too, were pressing next step(s) to improve the situation in the context represented by each speaker. If translated into a realistic and focused research agenda, and if taken up, these steps can move the field forwards.

Reference

UNESCO (2012). *World atlas of gender equality in education*. Paris: Author.

Gender and Mathematics Education in Africa

Nouzha El Yacoubi
University Mohammed V Rabat-Agdal. Morocco
e-mail: n.elyacoubi@yahoo.fr; nelyacoubi@fsr.ac.ma

Introduction

Even in the developed countries, where equity in Education was reached a long time ago, the rates of enrollment of girls in mathematics courses are relatively low. The gender problem and mathematics education has been studied since 1970 and some factors of that representativeness have been identified, in particular in the developed countries. But this area of research is still unexplored in the developing countries. In Africa, specifically, little research has been done until now on Gender and mathematics education despite the millennium goals recommending equity in education and the encouragement of African females to choose mathematics studies and to embrace scientific and technological careers.

Nevertheless, the role of women in the scientific development of Africa has been definitively recognized as a crucial and determining factor in building and reinforcing the continent’s scientific and technological capacities, because no African country can afford to leave 50 % of its population, out of its development process.

It is evident that Education in general in Africa was, and is till now, seriously affected by poverty, but with respect to the education of girls, history, religion and culture were, and they remain, important influencing factors.

These socio-cultural barriers are more pronounced when they come to scientific, technical and vocational education and, are unfortunately, tragic when they concern mathematics education.

The Current Situation in Africa

According to the UNESCO Institute for Statistics report published in September 2010, the lowest literacy rates were observed in sub-Saharan Africa, where the adult literacy rate for males is 71.6 and 53.6 % for females and in Northern Africa it is respectively 76.7 and 58.1 %. It should be highlighted that more than half of the adult population is still illiterate in the ten following countries: Gambia (55 %), Senegal (58 %), Benin (59 %), Sierra Leone (60 %), Guinea (62 %), Ethiopia (64 %), Chad (67 %), Burkina Faso (71 %), Niger (71 %), and Mali (74 %).

The net enrolment ratio in the primary school age population in sub-Saharan Africa countries is around 52.3 % girls (and 60.7 % boys), except in a very few countries where almost all girls of primary school age are enrolled at schools.

But there is a substantial drop out among girls at the secondary school level; it is due to socio-cultural (early marriage), financial reasons, institutional barriers and poor performance of girls. The Trends in Mathematics and Science Study (TIMSS) reported that between 68 and 90 % of African students in grade eight failed to reach the low benchmark in mathematics (IEA 2003). And unfortunately no significant progress was registered in TIMSS 2007. It is a pity that Africa was so poorly represented in such an important international assessment of the mathematics and science knowledge of fourth and eighth grade students. For example in TIMSS

2007, only six African countries have participated among 59 Countries namely: Algeria-Botswana-Egypt-Ghana-Morocco and Tunisia, and there was no African country among the 8 Benchmarking participants. The African countries participating in TIMSS 1995 through 2007 are as follows:

Country	Grade 4			Grade 8			
	1995	2003	2007	1995	1999	2003	2007
Algeria			x				x
Botswana						x	x
Egypt						x	x
Ghana						x	x
Morocco		x	x		x	x	x
Tunisia		x	x		x	x	x

As for upper secondary school, the enrollment ratio of girls is just about 17 % in Sub-Saharan Africa, so only a few girls have the opportunity to be enrolled in scientific classes, and among that population very few choose Mathematics courses. The best registered percentage for enrollment of girls in Mathematics at that level is about 30 % (Huggins and Randell 2007) and this percentage decreases with grade level and is about 10 % for the tertiary level.

The Causes

The factors identified in contributing to the gender problem in mathematics education in the developed countries remain valid for Africa, but other factors should be added like negative socio-cultural attitudes, household tasks at home, gender biased curriculum, poor didactic materials, lack of school facilities (dormitories), lack of sponsorship, unmotivated and unqualified mathematics teachers, lack of moral and financial parental support, lack of self confidence among the girls, poor performance in exams, and so on.

Interventions Introduced

First, the African Union (UN) has set up mechanisms and special committees at the ministerial level for monitoring progress towards attainment for Education For All (EFA). Gender mainstreaming has been identified and adopted as a strategy for achieving gender equity. In particular, special projects were launched with the aim of increasing the enrollment of African girls in Science, mathematics and technology, and to encourage African women to embrace scientific and technological careers. The programs included: “Special Project on Scientific, Technical and

Vocational Education of Girls in Africa in the framework of the UNESCO's Medium-Term Strategy" (1996–2001); "Africa's Science and Technology" project launched in 2007 by the African Union Summit of the Heads of State and Government; "Africa and Gender Equity" including "Science, technology and engineering education" in the UNESCO Medium-Term 2008–2013, as well as other initiatives sponsored by the World Bank, USAID, NEPAD (New Partnership for Africa's Development), UNICEF, and some non-governmental organizations (NGO's).

A special program for reducing gender disparities in science, technology and innovation has also been undertaken by the United Nations Economic Commission for the East African Community member countries. This, Huggins and Randell (2007) advocated, should serve as a case study for the other African regions.

There have been various other activities, for example, international conferences on Gender, Science and Technology were held in: Beijing (1995), Arusha (1997), Harare (1997) where national surveys of 21 African countries, assessing the participation of girls and women in scientific education and vocational training, were given, (Hoffmann-Barthes and Malpede 1997), Dakar (2000), Cairo (2006), Bamako and Ségou (2009), Paris (2010): UNESCO Expert Group Meeting.

Some camps and competitions for African girls have been organized through Africa, including: Camp of Excellence in Sciences and Mathematics for Young African Girls held, since 2000, in Mali and other African countries; Girls STEM (Science, Technology, Engineering and Mathematics) Camp initiative (Abuja 2011), Miss Mathématique (created in Ivory Coast and recently in Benin) and so on.

Conclusion and Suggestions

Despite these initiatives, females' participation in Africa, in Science, and Technology, and in particular in Mathematics, from primary through tertiary education to the career level is still very low. This could be explained by, among other factors, the persistent socio-cultural barriers, lack of clear policy guidelines for increasing the rates of enrollment of African girls in mathematics, lack of assessment and follow up of the various undertaken initiatives, lack of gender analysis expertise and so on.

A valorized image of African women in mathematics education and mathematics careers should be promoted and gender stereotypes with regard to mathematics careers should be countered by parents, teachers and all other actors in the school and societal environments.

Interventions for females should aim to achieve equity of outcomes rather than just equal access to educational opportunities in mathematics. So permanent assessment and relevant follow up are key elements in any undertaken initiative.

References

Aiken, L. (1970). *Attitudes Toward Mathematics*, Review of Educational Research, 40(1): 551-596.

Fennema, E. and Sherman, J. (1977). *Sex-related differences in mathematics achievement, spatial visualisation and affective factors*, American Educational Research Journal, 14(1): 51-71.

Walden, R. and Walkerdine, V (1985). *Girls and mathematics.* London: University of London.

Burton, L. (1990). *Gender and mathematics: An international perspective.* London: Cassell.

Kaiser-Messmer, G. (1993). *Results of an empirical study into gender differences in attitudes toward Mathematics,* Educational Studies in Mathematics, 25(3): 209-233.

Fennema, E.L and Leder, G (1995). *Mathematics and Gender.* New York: Teacher College Press.

Kiania, A.M. (1995). *Gender and mathematics achievement parity: Evidence from Post-Secondary Education.* Vol. 116 (4) p.586 – 591

B.Grevholm and G.Hanna (1995). *Gender and Mathematics Education*. Sweden, Lund University Press

Lamb, S (1997). *Gender difference in mathematics participation: An Australian participation*. Vol. 23(1); pp.105 -115.

Hoffmann-Barthes, & Malpede (1997). *Scientific, technical and vocational education of girls in Africa.* Retrieved from http://www.unesco.org/education/…/girls/reports.pdf

Working document1999 of UNESCO : Scientific, technical and vocational education for girls in Africa

TIMSS 2003 International Report on achievement in the Mathematics Cognitive Domain IEA (2004). Retrieved from http://timss.bc.edu/pdf/t03_download/t03mcogdrpt.pdf

Xin Ma (2004). *Current Trend in Gender Differences in Mathematics Performance: An International Update*. ICME 2004, TSG 26.

Asimeng-Boahene, L (2005). Gender Inequity in Science and Mathematics Education in Africa: The Causes, Consequences and Solutions. Education, Vol. 126, No. 4, PP. 711-72

Huggins, A., & Randell, S.K. (2007). Gender Equality in Education in Rwanda: What is happening to our girls? Retrieved from http://www.nuffic.nl/international-organizations/international-education-monitor/country-monitor/africa/rwanda/documents

D. Fisher, R. Koul&S. Wanpen (2008): Science*, mathematics and technology Education:Beyond cultural boundaries.* 5th SMTE Proceeding

V.S Mullis, M.O Martin and P.Foy (2008). *TIMSS 2007 International Report.* Retrieved from http://www.timss.bc.edu/timss2007/intl_reports.htm

Roland G. Fryer, Jr and Steven D. Levitt (2009). *An Empirical Analysis of the Gender Gap in Mathematics*. NBER Working Paper No. 15430. JEL No. I20

N.M. Else-Quest, J.S. Hyde and M.C.Linn (2010). *Cross-National Patterns of Gender Differences in mathematics*. A Meta-Analysis. Psychological Bulletin, Vol 136. No 1, 103-127.

UNESCO Institute for Statistics (2010). *Adult and youth literacy: global trends in gender parity*. UIS Fact Sheet. (September, 2010, No. 3).

United Nations. Economic and Social Council. Commission for Africa (2011). Mainstreaming gender in Science, Technology and Innovation Systems in the East African Community. Retrieved from http://www.uneca.org/…/codist-iireportexecutivesumma

Hanna David (2011). *Overcoming the gender gap in math,Science and technology : A 21st Century View*. Journal of Education and Social Research. Vol (1).

Nouzha El Yacoubi (2011). *Problème du Genre et Mathématiques en Afrique*. EDIMath, IMU-CANP, ICMI workshop, Bamako September 2011. (Could be provided by the author : n.elyacoubi@yahoo.fr)

Gender and Mathematics Education in Mexico

María Trigueros Gaisman
Instituto Tecnológico Autónomo de México, ITAM
e-mail: trigue@itam.mx

Introduction

In the area of Mathematics Education in Mexico, research on gender has produced interesting findings. Some studies have analyzed gender differences in relation to results attained on performance tests, while others have focused on more specific topics, such as spatial visualization, the differential relations that mathematics teachers may establish with female and male students at various educational levels, the distinct attitudes of girls and boys towards mathematics and towards the use of technology as an aid in teaching and learning mathematics.

At the same time there has been an emerging trend on the development of educational policies to reduce the gender gap in education at all levels, and to foster equity in academic work.

Results of Gender Studies at Elementary Education

Since the first study (Bosch and Trigueros 1996) no substantial gender differences have been observed in different tests in primary school (González 2003; Rivera 2003; Ursini, et al. 2010). However, PISA results indicate that gender differences favoring boys appear in the transition to secondary school. Studies on students' attitudes towards the subject (Ursini et al. 2004, 2007; Campos 2006; Ursini and Sánchez 2008; Ursini 2010) show that self-confidence favoring boys, and perception of mathematic as a male domain, start to develop at around 13 years of age, with boys attributing good performance to intelligence or skills and girls to effort and obedience. Interestingly, teachers were found to characterize differences in children's performance in the same terms (Ramirez 2006; Ramirez and Ursini 2008).

Regarding the use of technology in the learning of Mathematics, Ursini and Sánchez (2008) found that boys held a pragmatic view of technology while girls considered it as a resource to construct knowledge. They found that the use of technology helped to develop positive attitudes towards mathematics, particularly among girls, and suggested that using technology with guiding activities to foster group-work and discussion, helped to modify certain cultural patterns of conduct which can foster equity.

The use of technology also modified teachers conception of Mathematics learning (Trigueros and Lozano 2008; Rodriguez and Ursini 2008) with females focusing more on exploration and investigation to develop students' self-confidence, independence and creativity and males on developing skills needed by students to move forward in their education.

Results of Gender Studies at Higher Education

As at the elementary school level, in higher education no specific gender differences have been found in different studies in mathematics grades and the gender inequality in access to higher education detected in earlier studies (Bosch and Trigueros 1996) has been constantly decreasing. The largest university in Mexico reported in 2009 (Saavedra 2010) that the percentage of female students was larger than that of male students and that graduation percentages also favored women (56 % of women graduated against 50 % of men). However, there is still a severe under-representation of women in mathematics. Only 38 % of women enroll in mathematics programs, and 43 % of all students who graduate from these programs are women. The gender gap is greater when considering access to post-graduate education. In 2008 only 30 % of students in postgraduate programs were women, although in programs related to mathematics education female students comprised 45 %.

In a study involving university professors (Espinosa 2007), it was found that they considered male students to be more proficient in mathematics than females. They expressed the same beliefs as those found among teachers in elementary school about women being successful in mathematics because of their effort and discipline. Observation of classes detected a more passive attitude of female students and a tendency of male students to be more participative.

Although results show that, in general, female students are more perseverant in their studies, it seems that they still consider mathematics as a male domain, too competitive for women and that professors' beliefs tend to reinforce this conception.

Results of Gender Studies on Faculty

In the last few years there has been a large increase in the academic profession in Mexico, but problems related to gender in the access to work at universities are still present. Only 40 % of professors are women. This gap widens in the case of mathematics departments where women represent less than 25 % of all professors and many of them work in mathematics education (Saavedra 2010).

In terms of research, according to 2009 data from the National System of Researchers, women researchers in the area corresponding to physics and mathematics, which is the largest area of the system, represent only 19 % of all researchers with 23 % of them investigating in mathematics. Percentages of female researchers diminish as levels related to productivity rate increase, with only 3 % of women at the top level.

Some of these differences can be related to perception of mathematics as an occupation which is difficult to combine with family life, but results show gender as a determinant of the choice of mathematics as a field of study independently of school achievement.

Policies to Reduce the Gender Gap and Stereotypes

The ministry of Education has developed several initiatives since 2008 to incorporate the gender perspective in all the educational programs to help to change stereotypes that contribute to gender inequity. Among the more important are a revision of content of all the mandatory primary school textbooks from a gender perspective to foster a change in socio-cultural patterns, and the distribution of books on gender equity and prevention of violence for teachers and students. Together with international organizations, the ministry has developed projects for school communities where people participate in activities designed to reflect on gender stereotypes and their change. Technology is used to show different behavior patterns in particular situations together with questions asking users to reflect, comment and discuss if they find those behaviors appropriate or not and why.

A revision of the published policies from different universities in Mexico reveals that in the last 10 years there has been an increase in policies intended to foster women's access to higher education and to reduce the barriers for female faculty. Most of the universities nowadays have developed innovative programs to reduce inequalities for women researchers, teachers and students. These include mandatory seminars to discuss gender issues, awards designed for women faculty and students and specific programs to recruit women as faculty. However, only a few of them have been designed specifically to increase the number of women researchers in STEM related careers or to strengthen the academic position of women researchers and their participation in academic activities.

Some of these policies have shown some positive impact, however, their implementation is unequal in different regions of the country, and some of them have had implementation problems in practice. The effective advancement of women as faculty, in particular, seems to be prevented by everyday practices that tend to ignore policies, or at least to apply them in a limited way.

Conclusions

This review of studies on gender and mathematics in Mexico shows that although some advance in reducing the gender gap in mathematics has been achieved, there is still much work to be done in terms of policies and programs to change socio-cultural perceptions which inhibit the development of women in mathematics and mathematics related areas. More efforts are also needed to increase participation of women as faculty and as decision makers in areas related to mathematics, science and technology.

References

Bosch, C. & Trigueros, M. (1996). *Gender and mathematics in Mexico. In G. Hanna (Ed.). Towards gender equity in mathematics education. An ICMI Study*. (pp. 277-284). Kluwer Academic Publishers, Dordrecht, Boston, London.

Campos, C. (2006). *Actitud hacia las matemáticas: Diferencias de género entre estudiantes de sexto de primaria y tercer grado de secundaria*. Unpublished Masters Thesis, Department of Mathematics Education, Cinvestav-IPN, México.

Espinosa, C. (2007). *Estudio de las interacciones en el aula desde una perspectiva de género.* Unpublished Masters Thesis, Department of Mathematics Education, Cinvestav-IPN, México.

González, R.M. (2003). *Diferencias de género en el desempeño matemático. Educación Matemática. 15* (2), pp.129-161.

Rivera, M. (2003). *Diferencia de género en la visualización espacial: un estudio exploratorio con estudiantes de 2º de secundaria.* Unpublished Master Thesis, Department of Mathematics Education, Cinvestav-IPN, México.

Ramirez, M. P. and Ursini, S. (2008). *Influence of the female teachers' gender vision on the type of interactions they establish with boys and girls in the mathematics classroom.* Paper presented at ICME 11, Topic Study Group 32: Gender and mathematics education, Monterrey, México.

Rodriguez, C. & Ursini, S. (2008). *Social representation and gender in the teaching of mathematics with multimedia devices.* ICME 11, Topic Study Group 32: Gender and mathematics education, Monterrey, México.

Saavedra, P. (2010). *Trayectoria académica de las mujeres matemáticas en México*. http://docencia.izt.uam.mx/psb/ciencia.pdf (March 3rd, 2012).

Trigueros, M. & Lozano, M.D. (2008). *Teachers' assessment practices in mathematics courses. Does gender make a difference?* ICME 11, Topic Study Group 32: Gender and mathematics education, Monterrey, México.

Ursini, S. (2010). Diferencias de género en la representación social de las matemáticas: Un estudio con estudiantes de secundaria. In N. Blazquez, y F. Flores (Eds.). *Investigación feminista. Epistemología, metodología y representaciones sociales. Colección Debate y Reflexión. CEIICH.* Facultad de Psicología. UNAM. México.

Ursini, S., Ramírez, M. P., Rodríguez, C., Trigueros, M., and Lozano, M. D. (2010). Studies in Mexico on Gender and Mathematics. In H.J. Forgasz, J. Rossi Becker, K.H. Lee and O. Steinthorsdottir (Eds.) *International Perspectives on Gender and Mathematics Education*, *7*, 147-172.

Ursini, S. & Sánchez, G. (2008). Gender, technology and attitudes towards mathematics: A comparative longitudinal study with Mexican students. ZDM *The International Journal on Mathematic Education. 40,* 559-577.

Ursini, S., Ramirez, M. P. & Sánchez, G. (2007). Using technology in the mathematics class: How this affects students' achievement and attitudes. *Proceedings of the 8th ICTMT*, (Integration of ICT into Learning Processes). Czech Republic, University of Hradec Králové, [CD-ROM]

Ursini S., Sánchez G., & Orendain, M. (2004). Validación y confiabilidad de una escala de actitudes hacia las matemáticas y hacia las matemáticas enseñada con computadora. *Educación Matemática, 16*(3), 59-78.

Gender and Mathematics in Australia: A Downward Trajectory

Helen J. Forgasz
Monash University, Australia
e-mail: Helen.forgasz@monash.edu

Introduction

In this paper I draw attention to four areas in which gender equity in mathematics education has yet to be fully achieved in Australia, and where indications are that we are going backwards: (i) achievement in TIMSS and PISA; (ii) participation and achievement in higher level mathematics; (iii) use of technologies for mathematics learning; and (iv) public perceptions of gender issues in mathematics.

Australian Context

Despite laws and government policy decrying inequity, the realities of gender equity have not yet been fully realized in Australia. This is evident with respect to educational levels, occupations and salaries. Despite higher proportions of women than men having Year 12 or equivalent qualifications, bachelor-level degrees, and higher literacy and numeracy skill levels (Australian Bureau of Statistics 2012), graduate median starting salaries still show a $2,000 difference in favor of men, a consistent pattern over the past decade. When it comes to educational pathways leading to career options, males remain dominant in the physical sciences, and females in the humanities and social sciences.

TIMSS and PISA Results

Australian results in all years of TIMSS and PISA are shown in Table 1. The data reveal a disturbing pattern. Mean scores on TIMSS for grade 4 and grade 8 show an increasing gender gap favoring males, with the 2007 grade 8 score differences reaching statistical significance. For the PISA results, the gender gap in mean scores favors males in all years, but in 2006 and 2009, the score differences were also statistically significant.

Thomson et al. (2011, p. 299) claimed that “the re-emergence of gender difference as shown in PISA since 2006 are a salutary reminder to (Australian) schools and systems that this is still a significant issue and that if Australia is to improve its performance in mathematics, girls’ scores must improve”.

Participation and Achievement in Grade 12 Mathematics

The Victorian (Australia) grade 12 mathematics subject enrolment figures reveal a consistent pattern over time. Three mathematics options are offered at grade 12: Specialist Mathematics (most challenging, calculus-based), Mathematical Methods

Table 1 TIMSS (1995–2007) and PISA (2000–2009) results for Australia

	TIMSS 1995[a]	TIMSS 1999	TIMSS 2003	TIMSS 2007
Grade 4	F = 545, M = 547	No Grade 4	F = 497, M = 500	F = 513, M = 519
	2 points (M > F)		3 points (M > F)	6 points (M > F)
Grade 8	F = 532, M = 527	F = 524, M = 526	F = 499, M = 511	F = 488, M = 504
	5 points (F > M)	2 points (M > F)	12 points (M > F)	16 points (M > F)*
Final year of schooling	F = 510, M = 540			
	30 points (M > F)*			
15 year olds	F = 527, M = 539	F = 522, M = 527	F = 513, M = 527	F = 509, M = 519
	12 points (M > F)	5 points (M > F)	14 points (M > F)*	10 points (M > F)*
	PISA 2000	PISA 2003	PISA 2006	PISA 2009
15 year olds	F = 527, M = 539	F = 522, M = 527	F = 513, M = 527	F = 509, M = 519
	12 points (M > F)	5 points (M > F)	14 points (M > F)*	10 points (M > F)*

Legend: *F* female; *M* male; *statistical significant difference

Data sourced from various IEA, OECD, and Australian Council for Educational Research reports of TIMSS and PISA results

[a] Gill et al. (2002). Student achievement in England. Results in reading, mathematical and scientific literacy among 15-year-olds from OECD PISA 2000 study (p. 47). London: The Stationery Office (HMSO)

(includes calculus, pre-requisite for many university-level science-related courses), and Further Mathematics (least challenging, with an emphasis on statistics). The data in Fig. 1 reveal that enrolments have declined over time in Specialist mathematics while increasing in Further Mathematics. Yet, consistently, there have been higher proportions of males than females enrolled in all three options.

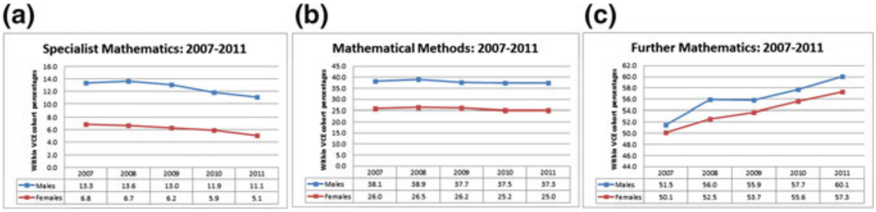


Fig. 1 Enrolment trends 2007–2009 in VCE mathematics subjects

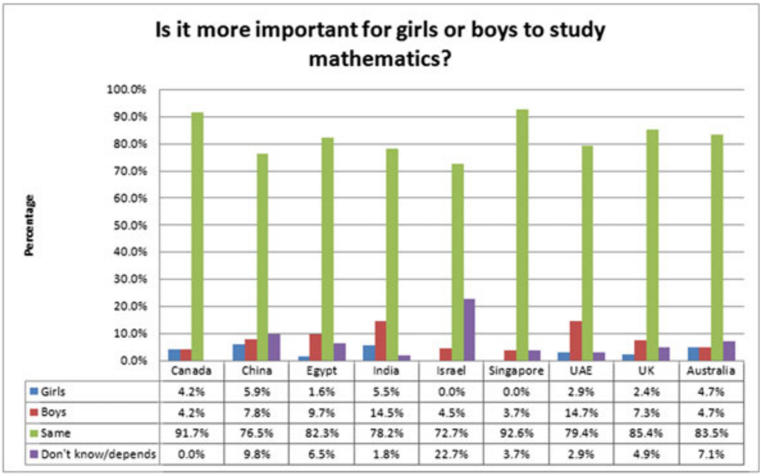
Table 2 Highest achievers (top 2 %) in VCE mathematics (2007–2009)

Subject	Gender	2007 (N = 65)		2008 (N = 60)		2009 (N = 59)	
		n	%	n	%	n	%
Specialist mathematics	Female	15	23.1	14	23.3	14	23.7
	Male	49	75.4	44	73.3	45	76.3
	Unknown	1	1.5	2	3.3	–	
Mathematical methods	Female	50	25.1	53	25.7	67	33.7
	Male	133	66.8	150	72.8	131	65.8
	Unknown	16	8.0	3	1.5	1	0.5
Further mathematics	Female	114	36.5	114	35.5	139	42.1
	Male	187	59.9	205	63.9	191	57.9
	Unknown	11	3.5	2	0.6		

An even more disturbing trend is found when the very highest achievers in these three mathematics options are considered, that is, the top 2 %. It is found that males outperform females at a rate that is disproportionate to their enrolments in these subjects (see Table 2 for data from 2007 to 2009). The data in Table 2 reveal that more than 50 % of the highest achievers in each of the three VCE subjects were male and that this pattern persisted over the three year period, 2007–2009.

Technologies for Mathematics Learning

The adoption of computers and calculators in mathematics classrooms has received much research attention in Australasia; less common is research incorporating gender as a variable—see Geiger et al. (2012) for an overview of recent Australasian research. Technology (and ICT), like mathematics, is considered a male domain. Hence, when technology is brought into the mathematics classroom, the effect of this combination with respect to gender issues clearly demands greater research interest than is evident. Researchers examining computer and/or sophisticated calculator use for mathematics learning and gender have found that those who appear to benefit more from the use of the technologies are those who are comfortable with the technology, that is, it is more likely to be boys than girls, but not necessarily boys with the highest mathematical capabilities. Much of the work on mathematics, technology, and gender has focused on the affective domain. Here it is clear that boys' confidence and competence levels with the technologies are more positive than girls', that boys more strongly than girls say they enjoy learning mathematics with technology, and that this is also the expectation of teachers and parents.



	Canada	China	Egypt	India	Israel	Singapore	UAE	UK	Australia
🟦 Girls	4.2%	5.9%	1.6%	5.5%	0.0%	0.0%	2.9%	2.4%	4.7%
🟥 Boys	4.2%	7.8%	9.7%	14.5%	4.5%	3.7%	14.7%	7.3%	4.7%
🟩 Same	91.7%	76.5%	82.3%	78.2%	72.7%	92.6%	79.4%	85.4%	83.5%
🟪 Don't know/depends	0.0%	9.8%	6.5%	1.8%	22.7%	3.7%	2.9%	4.9%	7.1%

Fig. 2 Response frequency by country: is it more important for girls or boys to study mathematics?

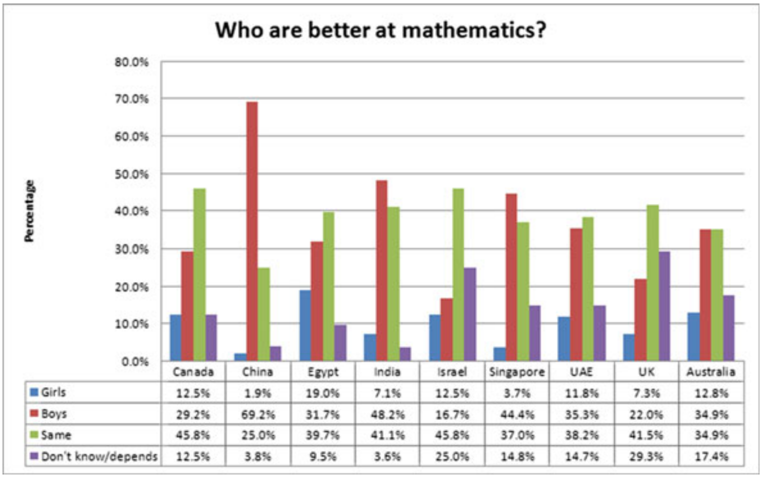
Public Perceptions of Gender Issues in Mathematics

Early explanatory models for gender differences in mathematics learning incorporated the views of society at large as critical contributing influences. Until recently, however, the views of the general public have rarely been sought. Very recent survey data reveal that the male stereotype is alive and well in the views of the Australian public and elsewhere in the world (e.g., Forgasz et al. 2012).

The extent of the view that mathematics is a male domain varies across the globe. In many countries, a large proportion of respondents to an online survey indicated that it is equally important for boys and girls to study mathematics (see Fig. 2). However, compared to girls, many believed that: boys are better at mathematics (see Fig. 3) and that parents and teachers also believe this, that boys are better with calculators and computers (see Fig. 4), and that boys are more suited to careers in science-related and computer occupational fields. As can be seen in Figs. 2, 3 and 4, Australian respondents' views on these issues fell somewhere between the extremes, with respect to response frequencies.

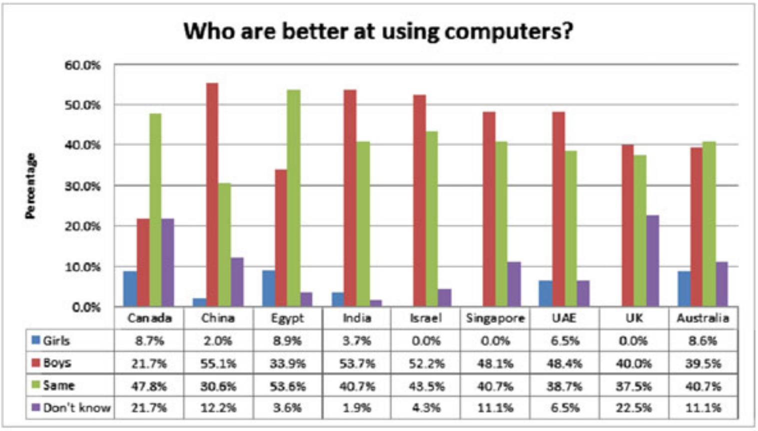
Final Words

The picture portrayed in the four brief snapshots above reveal a gendered world of mathematics learning that has changed little over the thirty year period in which research into this area began. The apparent gains made to reduce the gender gap



	Canada	China	Egypt	India	Israel	Singapore	UAE	UK	Australia
🟦 Girls	12.5%	1.9%	19.0%	7.1%	12.5%	3.7%	11.8%	7.3%	12.8%
🟥 Boys	29.2%	69.2%	31.7%	48.2%	16.7%	44.4%	35.3%	22.0%	34.9%
🟩 Same	45.8%	25.0%	39.7%	41.1%	45.8%	37.0%	38.2%	41.5%	34.9%
🟪 Don't know/depends	12.5%	3.8%	9.5%	3.6%	25.0%	14.8%	14.7%	29.3%	17.4%

Fig. 3 Response frequency by country: who are better at mathematics?



	Canada	China	Egypt	India	Israel	Singapore	UAE	UK	Australia
🟦 Girls	8.7%	2.0%	8.9%	3.7%	0.0%	0.0%	6.5%	0.0%	8.6%
🟥 Boys	21.7%	55.1%	33.9%	53.7%	52.2%	48.1%	48.4%	40.0%	39.5%
🟩 Same	47.8%	30.6%	53.6%	40.7%	43.5%	40.7%	38.7%	37.5%	40.7%
🟪 Don't know	21.7%	12.2%	3.6%	1.9%	4.3%	11.1%	6.5%	22.5%	11.1%

Fig. 4 Response frequency by country: who are better at using computers, girls or boys?

favoring males in participation, achievement, and attitudes during the 1980s and 1990s, appears to have been eroded to the point of a clear backward trajectory emerging in Australia. Believing that there was no longer a "girl problem" with respect to mathematics, with the consequential reduction in vigilance as curricula and practices have changed, may be largely to blame.

References

Australian Bureau of Statistics. (2012). *Gender indicators, Australia*. Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/mf/4125.0

Forgasz, H., Leder, G., & Gómez-Chacón, I. (2012, accepted). *Young pedestrians' gendering of mathematics: Australia and Spain*. Paper accepted for presentation at the annual conference of the Mathematics Education Research Group of Australia, Singapore.

Geiger, V., Forgasz, H., Tan, H., Calder, N., & Hill, J. (2012). Technology in mathematics education. In B. Perry, T. Lowrie, T. Logan, A. MacDonald, & J. Greenlees (Eds.), *Research in mathematics education in Australasia, 2008-2011* (pp. 111-142). Rotterdam, The Netherlands: Sense Publishers.

Thomson, S., De Bortoli, L., Nicholas, M., Hillman, K., & Buckley, S. (2011). *PISA in brief. Highlights from the full Australian report: Challenges for Australian education: Results from PISA 2009*. Retrieved from http://www.acer.edu.au/documents/PISA-2009-In-Brief.pdf

Taking a European Perspective

Lovisa Sumpter
School of Education and Humanities, Dalarna University, Sweden
e-mail: lsm@du.se

Taking a European Perspective

In this paper I look at how gender and mathematics education has been studied in Europe with the aim of highlighting trends but also discussing emerging themes. The main question posed in this paper is: What research focus in gender and mathematics can we find in papers that have been published during the years of 2007–2011? Gender is here defined as an "analytic category which humans think about and organize their social activity rather than as a natural consequence of sex difference" (Harding 1986, p. 17), emphasizing gender as something individuals do and create rather than something you have as a person. In order to talk about different foci of research on gender and mathematics, I follow Bjerrum Nielsen (2003) and use the following four aspects of gender: (1) structural gender, e.g. research of different groups within structures such as professions, level of education or social background; (2) symbolic gender e.g. studies looking at symbols and discourses that are attributed to a specific gender creating norms telling us what is normal and what is deviant; (3) personal gender e.g. studies on how girls and boys feel or think about various items or studies looking at individual's development of gender; and, (4) interactional gender e.g. research looking at how people interact with each other or how the social context is created. By using these four aspects different parts of the concept ‘gender’ can be emphasized.

Method

The data that constitute the base for the analysis were generated from the ERIC database, February 2012. The search terms were ‘mathematics’ and ‘gender’, peer-reviewed journal articles published within the last 5 years. By choosing only mathematics and not ‘math’ or ‘maths’ some papers were inevitably not included. The number of papers resulting from this search was 585. Thereafter I classified what could be considered European research; defined here as data collected in at least one European country, although the author/s could be positioned in any country. The list was narrowed down to 181 papers. Using Harding’s (1986) definition of gender means that I have excluded all papers *only* using gender to denote division of sex, e.g. studies looking at sex-differences in performance (total 51 papers). I also excluded papers not on mathematics (e.g. using mathematics as a notion of intelligence or focusing on another subject e.g. chemistry, 23 papers) and papers that have a general international scope (11 papers). Most papers within this category were large-scale comparisons, e.g. results from international tests. Finally, four papers (all from Turkey) were not available online and therefore could not be analyzed. This left a total of 92 papers. The papers were divided into the four categories. If a paper dealt with multiple aspects, the main focus was selected. This is a simple division and it should be stressed that most papers are more complex and touch several aspects either in the background to the study, factors in the analysis and/or in the discussion of results. However, this division provided information for discussing main trends and themes.

Results and Discussion

The results were summarized in tables. Table 3 shows the number of papers produced by the different European countries in alphabetical order and the aspect of gender.

One paper has been marked as ‘Europe’ since the focus of the paper was evenly distributed among the participating countries; Garcia-Aracil (2008) compared college major and earning gaps in seven European countries. The countries that produced most papers during this period are UK and Germany followed by Finland. There are differences between the countries in which aspects of gender have been studied. Papers from UK, Finland, Sweden and Israel covered all aspects of gender whereas there was no paper focusing on interactional gender from Germany or Turkey. Looking closer at the papers from Germany, all of them were quantitative

Table 3 Aspect of gender and number of papers by country

Country	Number	Gender aspect[c]
Europe[a]	1	1
Belgium	2	1, 1
Croatia	1	3
Cyprus	1	1
Estonia	0.5[b]	4
Finland	12.5[b]	1, 1, 1, 1, 1, 2, 2, 2, 3, 3, 3, 4, 4
France	3	2, 3, 3
Germany	16	1, 1, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3
Greece	1	3
Iceland	2	1, 1
Ireland	2	1, 3
Israel	5	1, 1, 2, 3, 4
Italy	2	2, 2
The Netherlands	7	1, 1, 1, 3, 3, 3, 3
Norway	2	1, 1
Spain	3	2, 3, 3
Sweden	6	1, 1, 2, 3, 3, 4
Turkey	7	1, 1, 1, 2, 2, 3, 3
UK	17	1, 1, 1, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4

Note The number of papers is 92

[a] Seven European countries

[b] Comparative study Finland and Estonia

[c] Gender aspect: *1* structural; *2* symbolic; *3* personal; *4* interactional

studies, often large-scale, and most of them (10 of 12) were published in a journal not specific for mathematics education.

Let us look at the main focus of the selected papers. This is the number of papers covering different aspects of gender: structural, 30 papers (33 %); symbolic, 18 papers (20 %); personal, 38 papers (41 %); interactional, 6 papers (7 %). Most papers focused on structural gender or personal gender, whereas only six papers were on interactional gender. What these six papers have in common is that all of them looked at people's conceptions in relation to each other or to a development, e.g. Francis (2008) who studied interactions in different classes, where one of the classes presented is a math class. The majority of papers in structural and symbolic gender were quantitative studies, e.g., Ammann et al. (2010) who studied the number of students enrolled in undergraduate mathematics courses and Räty and Kärkkainen (2011) who looked at parents' stereotyping. We find a bigger variation of methods for data collection moving to the category 'personal gender', e.g. Mendick (2008) who used interviews when studying two students' conceptions about transitions between levels. Four papers focused on mathematics at preschool level. Klein et al. (2010) studied pre-school teachers' attributions of children's achievements in mathematics, and Ojala and Talts (2007) looked at pre-school teachers' evaluations of achievements. Palmer (2009, 2010) studied pre-school teacher education when writing about alternative mathematical practices.

As mentioned earlier, German papers were mainly found in non-mathematics education journals. This seemed to be a general trend. The top five journals in terms of publications relevant for this review were: *British Educational Research Journal*, 7 papers (8 %); *European Journal Psychology Education*, 5 papers (5 %); *Gender and Education*, 5 papers (5 %); *International Journal of Mathematical Education in Science and Technology*, 5 papers (5 %); *Scandinavian Journal of Educational Research*, 4 papers (4 %). The discussion about mathematics and gender mainly took place in journals that do not aim specifically towards mathematics education.

With respect to selecting areas for future research, the first topic I see as an emerging theme is research focusing on interactional gender. Four of the six papers on this aspect were published in 2010, possibly indicating an upcoming topic. Overall, there were few studies looking at "doing gender" in educational settings compared to the number of papers studying people "having gender". The most common type of paper was one reporting a large-scale quantitative study focusing on conceptions of different kinds, often related to mathematical achievement. Very few projects drew on qualitative measures in order to find out more about what 'doing gender' implies at various levels. Also, not many papers had a strong mathematical focus. A second theme for future is research looking at more content specific issues. The third area I see as an area that as yet has not been addressed in detail is research focusing on children under the age of five. There were only four papers aiming at pre-school mathematics, but not a single paper focused on pre-school students themselves. If we are to understand how personal gender is constructed, we need to know more about the process from the very beginning.

References

Ammann, C., Frauendiener, J. & Holton, D. (2010). German undergraduate mathematics enrolment numbers: background and change. *International Journal of Mathematical Education in Science and Technology, 41(4)*, 435-449

Bjerrum Nielsen, H. (2003). *One of the boys? Doing gender in Scouting.* Génève: World Organization of the Scout Movement.

Francis, B. 2010. Re/theorising gender: Female masculinity and male femininity in the classroom? *Gender and Education, 22 (5),* 477–490.

Garcia-Aracil, A., (2008). College major and the gender earnings gap: a multi-country examination of postgraduate labour market outcomes. *Research in Higher Education 49*, 733–757.

Harding, S. (1986). *The Science Question in Feminism.* Ithica, NY: Cornell University Press.

Klein, P.S., Adi-Japha, E., & Hakak-Benizri, S. (2010). Mathematical thinking of kindergarten boys and girls: similar achievement, different contributing process. *Educational Studies in Mathematics, 73*, 233-246.

Mendick, H. (2008). Subtracting difference: troubling transitions from GCSE to AS-level mathematics. *British Educational Research Journal 34 (6).* 711–732.

Ojala, M., & Talts, L. (2007). Preschool achievement in Finland and Estonia: Cross-cultural comparison between the cities of Helsinki and Tallinn. *Scandinavian Journal of Educational Research 51(2)*, 205–221.

Palmer, A. (2009). "I'm not a "maths-person"! Reconstituting mathematical subjectivities in aesthetic teaching practices. *Gender and Education 21(4)*, 387–404.

Palmer, A. (2010). 'Let's dance!' Theorising alternative mathematical practices in earlychildhood teacher education. *Contemporary Issues in Early Childhood 11 (2)*, 130–143.

Räty, H. & Kärkkainen, R. (2011). Are parents' academic gender stereotypes and changes in them related to their perceptions of their child's mathematical competence? *Educational Studies, 37(3)*, 371-374.

Gender and Mathematics Education in the United States

Sarah Lubienski
University of Illinois at Urbana-Champaign, USA
e-mail: stl@illinois.edu

Introduction

Over the past several decades, the United States has made considerable progress toward gender equity in education. Substantial achievements have been made, such as the closure of gender gaps in high school mathematics course taking and college attendance (Lacampagne et al. 2007). In fact, some U.S. writers now argue that girls are more advantaged than boys, given that girls tend to score higher in reading, get better grades in school, and complete more bachelor degrees (e.g., Sommers 2000). However, gaps remain in mathematics achievement, affect, and ultimately the pursuit of high-status STEM careers.

Achievement

U.S. gender disparities in secondary mathematics achievement generally favor boys and are similar in size to those of many other industrialized nations (Else-Quest et al. 2010; OECD). However, TIMSS data suggest that significant mathematics score gaps favoring boys occur earlier in the U.S. than in most participating countries

(Mullis et al. 2008). Most recently, studies using data from the U.S. Early Childhood Longitudinal Study (ECLS), indicate that U.S. boys' and girls' mathematics proficiency is similar at the start of school (roughly age 5), but a significant male advantage emerges by age 8 (Robinson and Lubienski 2011). Regardless of grade level or dataset, U.S. mathematics gender gaps tend to be largest at the upper end of the achievement distribution (McGraw et al. 2006; Robinson and Lubienski 2011).

Affect

As in most countries participating in TIMSS and PISA, girls in the U.S. report having substantially less mathematical confidence than boys (Else-Quest et al. 2010). Recent analyses of ECLS data reveal that this trend exists already in U.S. primary schools, with gaps in confidence being substantially larger than gaps in both actual performance and interest in mathematics. Moreover young students' confidence predicts later gains in both mathematics achievement and interest (Lubienski et al. 2012).

Careers

Although women in the U.S. are at least as likely as men to pursue many science-related careers (e.g., biology), women remain under-represented in higher-paying, mathematics-intensive fields, such as engineering and computer science, in which women earn less than 20 % of bachelor's degrees (Snyder and Dillow 2011). These career patterns are a primary factor underlying earnings disparities among male and female college graduates, with U.S. women earning only 69 % of comparable men's salaries (Dey and Hill 2007).

Teachers and Students

U.S. girls are more compliant than boys in school (Rathbun et al. 2004), and boys are more likely than girls to exhibit a performance goal orientation, striving to "show off" their knowledge (Kenney-Benson et al. 2006). These patterns could cause boys to use more bold, invented methods during problem solving and could shape teachers' and students' views of who is "smart" (Fennema et al. 1998). Past research has revealed ways in which U.S. teachers attend more to boys than to girls (Sadker and Sadker 1986), and to attribute boys' mathematics success to ability and girls' success to effort (Fennema et al. 1990). More recent research reveals that U.S. elementary teachers rate boys' proficiency in mathematics—but not in reading—

higher than that of girls with equal test scores and similar classroom behavior (Robinson et al. 2012).

The Field of Mathematics

Recent research highlights subtle barriers to women's participation in mathematical fields. Lacampagne et al. (2007) emphasize the importance of women having a sense of belonging in mathematics, good relationships with faculty, flexibility in negotiating family responsibilities, and mathematical confidence. However, U.S. males remain more confident of their mathematical abilities relative to females with equal test scores (Correll 2001). Given that the opposite is true for reading, societal views about mathematics and gender likely influence students' perceptions of their own abilities.

Lingering Questions

The findings summarized thus far raise several questions. For example, why do girls report less mathematical confidence than their achievement merits? Why do U.S. teachers under-rate girls' competence in mathematics but not in literacy, relative to boys with similar behavior and achievement? (Robinson et al. 2012).

And finally, why do gaps in mathematics-related STEM fields remain so substantial despite the closure of key gaps in U.S. mathematics course-taking and college mathematics majors? One U.S. study provides an interesting insight. Males were nearly four times as likely to choose a quantitative college major than females with equal mathematics achievement, but this pattern was largely due to women's relatively strong verbal abilities (Correll 2001). In other words, women had other options, consistent with Eccles' (1986) argument that women make reasoned choices and do not simply avoid math. Interventions could fruitfully target girls' knowledge about ways in which a combination of mathematics and verbal skills could be a powerful asset in meaningful, STEM-related careers.

A Final Word About Research Methods for Studying Gender and Mathematics

The findings synthesized above are from a wide variety of qualitative and quantitative studies. Given the continued development of more sophisticated statistical methods, as well as the availability of large-scale, longitudinal datasets containing hundreds of variables, quantitative research on gender can go far beyond simply confirming the persistence of gaps in mathematics performance (Lubienski 2008). However, qualitative studies are continually needed to explore the factors underlying relationships found in large-scale data, as well as to develop the most important variables to be added to future, large-scale efforts.

References

Correll, S. J. (2001). Gender and the career choice process: The role of biased self-assessments. *American Journal of Sociology*, *106*(6), 1691-1730.

Dey, J.G. & Hill, C. (2007). *Beyond the pay gap*. Washington, DC: American Association of University Women Educational Foundation.

Eccles, J.S. (1986). Gender-roles and women's achievement. *Educational Researcher*, *15*(6), 15- 19.

Else-Quest, N.M., Hyde, J.S., & Linn, M.C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136* (1), 101-127.

Fennema, E., Carpenter, T. P., Jacobs, V. R., Franke, M. L., & Levi, L. W. (1998). A longitudinal study of gender differences in young children's mathematical thinking. *Educational Researcher, 27*(5), 6-11.

Fennema, E., Peterson, P. L., Carpenter, T. P., & Lubinski, C. A. (1990). Teachers' attribution and beliefs about girls, boys, and mathematics. *Educational Studies in Mathematics, 21*, 55-69.

Kenney-Benson, G.A., Pomerantz, E.M., Ryan, A.M., & Patrick, H. (2006). Sex differences in math performance: The role of children's approaches to schoolwork. *Developmental Psychology, 42*(1), 11-26.

Lacampagne, C. B., Campbell, P. B., Herzig, A. H., Damarin, S., & Vogt, C. M. (2007). Gender equity in mathematics. In S. S. Klein (Ed.), *Handbook for achieving gender equity through education* (2nd ed., pp. 235–252). Florence, KY: Taylor and Francis.

Lubienski, S. T. (2008). On "gap gazing" in mathematics education: The need for gaps analyses. *Journal for Research in Mathematics Education, 39(4), 350-356.*

Lubienski, S. T., & Ganley, C., & Crane, C. (2012). Unwarranted uncertainty: Gender patterns in early mathematical confidence, interest and achievement. Paper to be presented at the American Educational Research Association, Vancouver.

McGraw, R., Lubienski, S. T., & Strutchens, M. E. (2006). A closer look at gender in NAEP mathematics achievement and affect data: Intersections with achievement, race and socio-economic status. *Journal for Research in Mathematics Education, 37*(2), 129-150.

Mullis, I. V. S., Martin, M. O., & Foy, P. (2008). TIMSS 2007 international mathematics report. Chestnut Hill, MA: Boston College.

Organisation for Economic Co-operation and Development. (2009). *Equally prepared for life? How 15-year-old boys and girls perform in school*. Paris, France: Author.

Rathbun, A. H., West, J., & Germino-Hausken, E. (2004). *From kindergarten through third grade: Children's beginning school experiences* (NCES 2004-007). Washington, DC: National Center for Education Statistics.

Robinson, J.P., & Lubienski, S.T. (2011). The development of gender achievement gaps in mathematics and reading during elementary and middle school: Examining direct cognitive assessments and teacher ratings. *American Educational Research Journal*, *48*(2), 268-302.

Robinson, J. P., Lubienski, S. T., & Copur-Gencturk, Y. (2012). Gender-biased perceptions fuel early mathematics gender gap. Paper to be presented at the American Educational Research Association, Vancouver.

Sadker M., & Sadker, D. (1986). Sexism in the classroom: From grade school to graduate school. *Phi Delta Kappan*, *68*, 512-515.

Sommers, C. H. (2000). *The war against boys: How misguided feminism is harming our young men*. New York, NY: Touchstone Books.

Snyder, T. D. & Dillow, S. A. (2011). *Digest of Education Statistics 2010 (NCES 2011-015).* National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington DC.

Panel on "Gender and Mathematics Education Revisited"—Final Comments

Gilah C. Leder
Monash University, Australia
e-mail: Gilah.Leder@monash.edu

> In our culture … being "good in math" is 'being bright', and being bright in mathematics is associated with control, mastery, quick understanding, leadership. Unsuccessful mathematics implies the opposite … (Reisman and Kaufman 1980, p. 36)

The journey into the field of gender and mathematics education provided by the panelists served as a return visit to the field for some of the audience but signified a new, previously untraveled journey for others. Given the importance in many countries attached to mathematics, it is an intellectual journey well worth the effort. So what have we learnt?

Irrespective of the theoretical stance taken, it seems that there is considerable commonality in the external factors likely to facilitate or impede the pathway towards achieving gender parity and gender equality: the cultural, social, political and economic environments, systemic factors, historical precedents and community expectations.

Similarities permeate the different presentations. Despite decades of research it seems that evidence is still found of subtle but consistent gender differences in favor of males, particularly in mathematics performance and participation in post compulsory and advanced mathematics courses, on selected mathematical tasks on standardized or large scale tests, and among high performing students.

Some of the special interventions introduced in Western countries to redress demonstrated achievement disparities in mathematics learning have been taken up more widely, directly or with realistic adaptations.

Unanticipated between country differences were also reported. For example, research from Mexico suggested that girls are advantaged by technology—a finding not replicated in Australia. Perceptions (by the public in Australia) that teachers believe boys and girls are equally good at mathematics are seemingly at variance with reports from the USA that teachers rate boys and girls differently with respect to mathematics achievement.

Clearly, challenges remain before the goals of gender parity and gender equality are achieved, or even principally achieved, in an enlarged number of countries. The more modest goal of improved access for all, including females, to mathematics learning also remains elusive.

Constructive and contextually relevant recommendations have been made in the various panel presentations. The claim that "feminism has made its greatest contributions by asking new questions, often at odds with fundamental assumptions in a discipline" (Schiebinger 2001, p. 187) provokes a set of further questions which sharpen areas worthy of renewed and careful scrutiny. For example: Who, in our different countries, decides who should benefit from education; what mathematics should be taught, and to whom? Who determines educational and scientific priorities promoted for short and longer term funding? These are among practical starting points. For any changes in the current answers to be achieved, followed by constructive practical interventions, close cooperation between individuals and organizations is required. How well this challenge is met warrants careful and persistent monitoring.

References

Reisman, F. K., & Kauffman, S. (1980). *Teaching mathematics to children with special needs*. Columbus, OH: Charles E. Merrill Publishing Company.

Schiebinger, L. (2001). *Has feminism changed science?* Cambridge, Massachusetts: Harvard University Press.