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Promoting effective mathematics teaching

Analyzing teacher enactment of grade 8 mathematics curricula using TIMSS data

SUMMARY

- Aligning official curricular intentions with teacher instructional decisions in the classroom is widely believed to lead to improved student performance.
- As active agents and decision makers in this process, rather than as passive deliverers of prescribed curricular content, teachers make significantly different instructional decisions in enacting the curriculum.
- In TIMSS, teachers in high-achieving education systems reported teaching more challenging mathematics content; teachers in low-achieving education systems reported spending more time teaching mathematics, and had high performance expectations.
- In all education systems participating in TIMSS, teachers' enactment of a mathematics curriculum diverged considerably from official intentions.
- Curriculum- and teacher-related policies should focus on ways to enable teachers to better adapt the intended curriculum to specific contexts and student populations.

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IMPLICATIONS

- Setting high standards for the overall mathematics curriculum and ensuring teachers adhere to these standards may not necessarily lead to better learning outcomes.
- Mathematics performance in TIMSS appears to be independent of teachers' instructional alignment with the official curriculum.
- The analyses show significant gaps between the intended and implemented grade 8 mathematics curricula in many TIMSS education systems, regardless of performance.
- Education systems should foster conditions that enable teachers to better enact the intended mathematics curriculum, taking into account students' previous knowledge and current needs.
- Policies regarding teacher supervision, mentoring, accountability, and evaluation, should support teacher enactment of the curriculum.

INTRODUCTION

As curriculum enactors, teachers actively engage in making decisions about the prescribed curriculum. In doing so, they create opportunities to learn that vary by classroom, school, and system. Understanding teacher decisions is key to improving student performance. While many policies are designed to influence teacher pedagogy, particularly their alignment with curricular intentions, research continues to focus on how and why teachers implement the curriculum in particular ways. Especially important are studies that examine how instructional practices differ within and between education systems, and with what impact on learning.

The IEA's Trends in International Mathematics and Science Study (TIMSS; see https://www.iea.nl) provides an excellent comparative platform to explore variation in teacher instructional practices (Mullis & Martin, 2013). This Brief examines the mathematics content teachers actually teach during the grade 8 in low-performing and high-performing education systems and focuses on two critical questions: To what extent do teachers provide significantly different learning opportunities to students in low and high performing education systems? To what extent are these differences related to the degree to which teachers align their instructional practices with the prescribed curriculum?

DATA AND KEY MEASURES

After assessing their average student results for grade 8 mathematics in TIMSS 2007, 2011, and 2015 (Mullis et al., 2008, 2012, 2016), we selected and categorized 15 education systems as either low or high performers in mathematics (see Appendix for details). An education system was categorized as high performing if their average grade 8 mathematics score in the three TIMSS cycles was above the TIMSS scale center point (500 points), and low performing if it was below the TIMSS scale center point.

We examined three measures of the curriculum: content topics, instructional strategies, and instructional time (see Appendix for further details). For each measure we calculated the percentage of teachers that covered the mathematics content topics, or employed the instructional strategies, and the average percentage of instructional time devoted to the teaching of mathematics by education system. Measures for the enacted curriculum were taken from teacher reported data. While this is the best data source available, the surveyed teachers do not constitute a representative sample of all teachers. TIMSS 2015 sampled and tested grade 8 students and the teachers surveyed were their mathematics teachers and not a sample of all grade 8 teachers (Mullis & Martin, 2013).

Question 1. To what extent do teachers enact a different grade 8 mathematics curriculum in low and high performing education systems, thereby providing students with different learning opportunities?

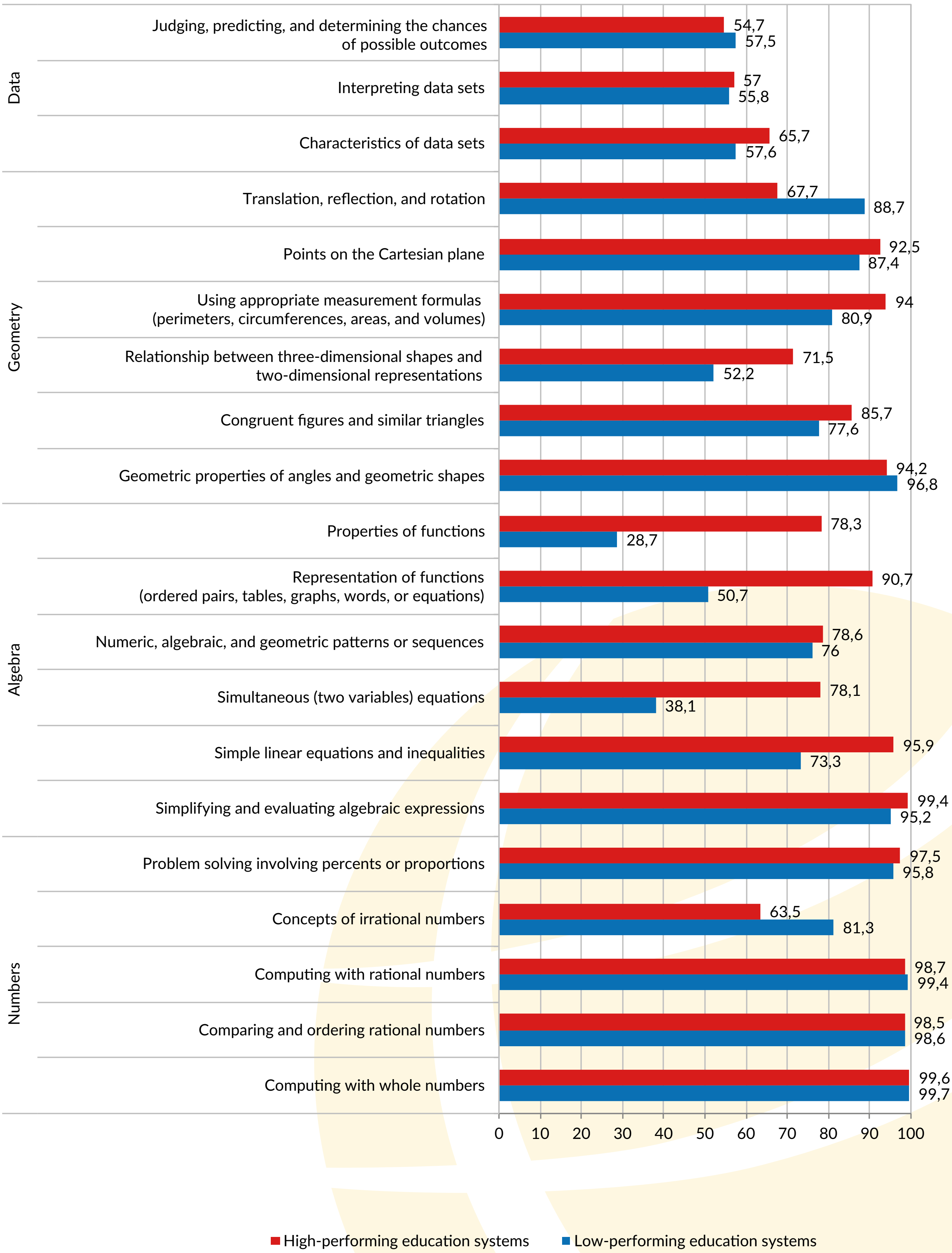
All three measures of the enacted curriculum varied across and within education systems. In other words, the analyses did not identify distinctively different patterns of learning opportunities among either the low- or high-performing education systems.

CONTENT TOPICS

Content topics taught either prior to or during grade 8 were reported by teachers, and were based on the 18 content topics across four domains of mathematics included in the TIMSS 2015 framework (Mullis & Martin, 2013). We found that, in general, teachers in both low- and high-performing education systems enact quite similar mathematics curricula, covering topics from all four content domains: number, algebra, geometry and data (see Figure 1). In all education systems, teachers reported high coverage of number topics, which are usually taught from the early grades of primary education. By contrast, there were important differences in the coverage of algebra and geometry topics, especially the more advanced topics that are often taught in higher grades. For each content domain, a lower percentage of teachers in low-performing education systems reported covering more complex content topics, with two exceptions: concepts of irrational numbers, and translation, reflection and rotation. It should be noted, however, that the latter content involves three subtopics that may be covered in different grades. Reflection, for example, is often taught earlier in the schooling progression. Thus, for this particular grouping in the questionnaire, teacher reports may be less accurate. In general, teachers in both low- and high-performing education systems reported covering algebra, geometry and data topics less extensively than number topics.

At the system level, the grade at which topics are introduced, the number of topics covered per grade, and the consistency with which topics are covered from grades 1 to 8 varied across education systems.

Figure 1: Percentage of teachers who reported teaching mathematics topics during or before grade 8 in both low- and high-performing education systems

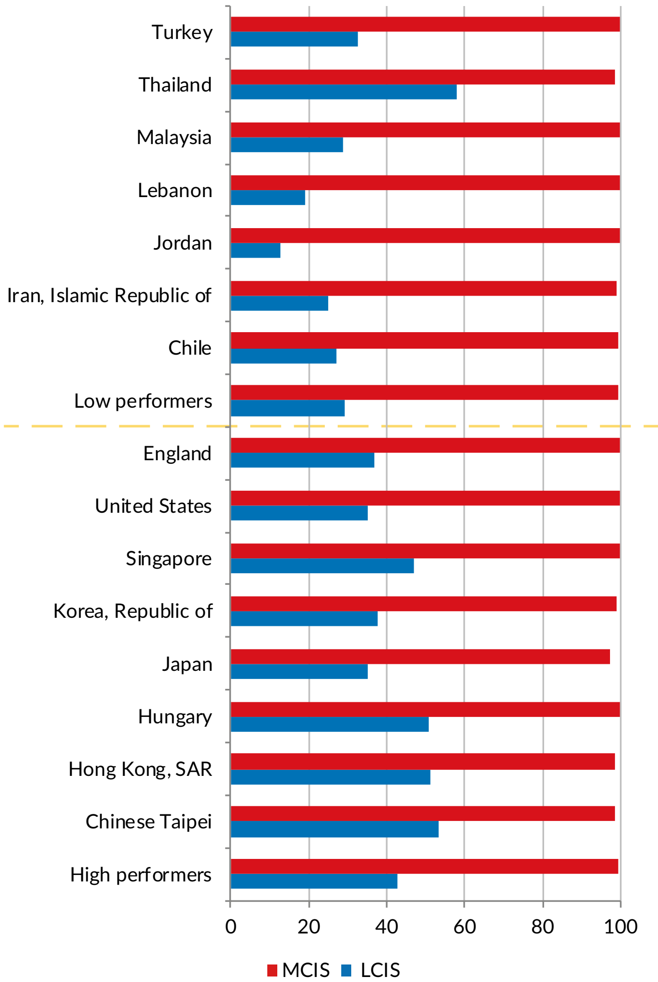


INSTRUCTIONAL STRATEGIES

As in previous cycles (2007 and 2011), teachers in the 2015 cycle of TIMSS reported how often they employed specific instructional activities in their classroom teaching. Questions relate to how teachers explain new mathematics content, whether students are asked to memorize rules, procedures, and facts, and whether students decide on their own problem-solving procedures. From these reports we created two variables by categorizing activities by the kinds of the cognitive processes they entail (see Appendix): we term these as (1) less challenging instructional strategies (LCIS) and (2) more challenging instructional strategies (MCIS). Activities associated with remembering, which is considered to be one of the more basic processes according to Bloom's revised taxonomy (Krathwohl, 2002), were classified as LCIS, whereas more analytical, interpretative or communicative processes were categorized as MCIS. We then calculated the percentage of teachers who emphasized to a lesser or greater extent each type of instructional strategy.[1]

In all education systems, almost all teachers reported exposing students (with moderate or high frequency) to more challenging instructional strategies (Figure 2). The use of less challenging instructional strategies was less prevalent and varied by system. Perhaps surprisingly, 57.9 percent of teachers in low-performing education systems reported frequently covering MCIS, against only 44.4 percent of teachers in high-performing education systems. Conversely, 42.9 percent of teachers in high-performing education systems and 29.2 percent of teachers in low-performing systems reported moderate to high coverage of LCIS.

Figure 2 : Percentage of teachers that exposed students with moderate or high frequency to more challenging (MCIS) and less challenging (LCIS) instructional strategies



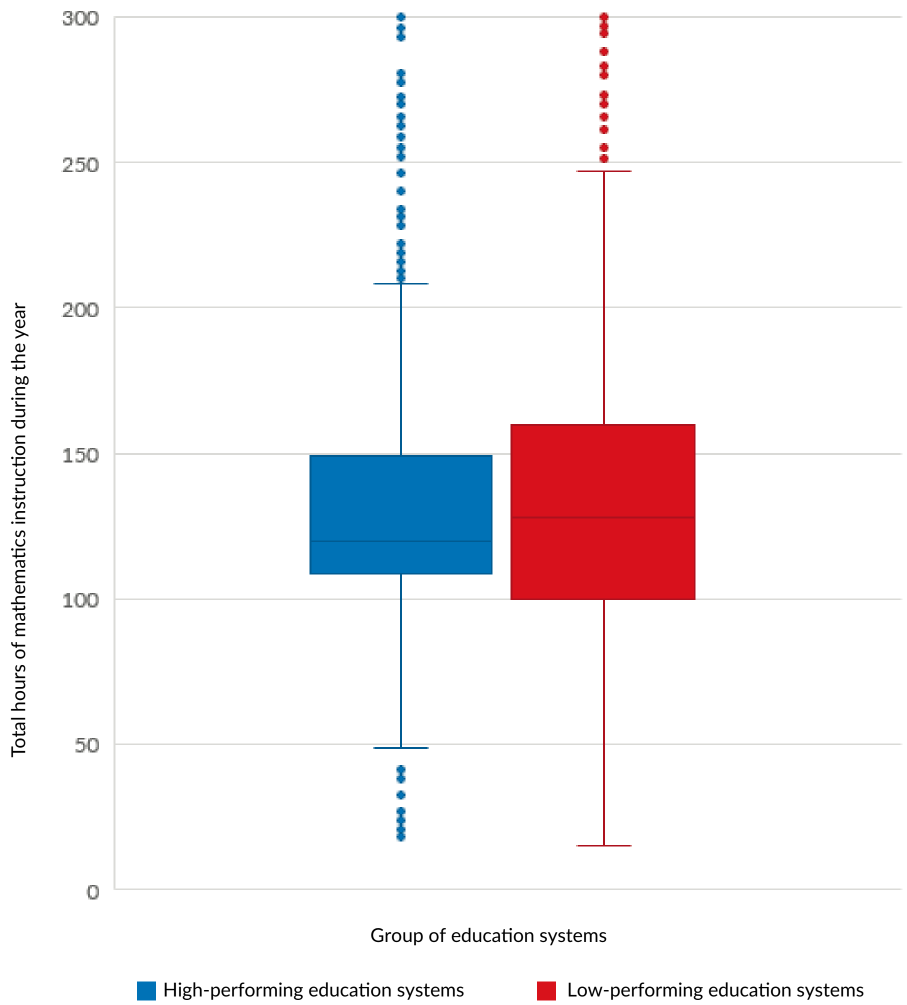
ENACTED INSTRUCTIONAL TIME

Actual instructional time was measured by the number of hours of mathematics instruction during the year, according to teacher and school questionnaire data. The analysis shows that annual instructional time spent on mathematics in the low-performing group of education systems varied considerably more between the 25th and 75th percentiles than that in the high-performing education systems[2] (Figure 3). Within each group of education systems, instructional time also differed significantly. Overall, teachers reported that the opportunity to learn mathematics in relation to instructional time varied significantly across education systems, from between 40 or 50 hours per year, to 220 hours per year.

1 The response categories for each item were: (a) every or almost every lesson; (b) about half of the lessons; (c) some lessons; and (d) never. We then averaged the responses for each type of instructional strategy to determine whether the emphasis on that strategy was weak, medium or strong.

2 Outliers (< 5 percentile points) in both groups were eliminated.

Figure 3: Distribution of annual mathematics instructional time in low- and high-performing education systems



Question 2: To what extent are differences in the grade 8 mathematics curricula between low- and high-performing education systems attributable to the degree of alignment of teachers' instructional practices with the prescribed curricula?

INSTRUCTIONAL ALIGNMENT

To compare the intended curricula with the enacted curricula, we analyzed content and instructional time data reported in the TIMSS 2015 curriculum questionnaire. For each education system and mathematics topic, we calculated the percentage of teachers who reported covering the topic, and related such percentages to the inclusion or non-inclusion of these topics in the intended grade 8 curricula. The intended and enacted instructional times were compared using measures of the percentage of time allocated and devoted to teaching mathematics out of the total available annual instructional time.

In terms of content, both low- and high-performing education systems showed important gaps between the intended and enacted curricula. Although the average percentage difference between these was larger for the low-performing group, ≥50 percent of the teachers surveyed in both groups diverged from the intended curriculum for some of the topics, and this was true for all content domains. High-performing education systems, such as England, Hong Kong, the Republic of Korea, Singapore, and the United States displayed differences in three or more content domains (Table 1).

In both groups, there were some education systems where <50 percent of teachers covered the intended number topics. However, topics that were not included in the official curricula were taught by a considerable percentage of teachers in both groups of education systems. For example, in the case of algebra topics, the average percentage of teachers in the low-performing group who reported teaching topics that were not included in the official curricula was similar to that in the high-performing group (29.7% and 24.7%, respectively).

Meanwhile, 60.3 percent of teachers in high-performing education systems but only 49.6 percent of teachers in low-performing countries reported covering intended algebra topics.

In the content domain of geometry, although the average coverage of non-prescribed topics was higher in low-performing (36.1%) than in high-performing education systems (22.9%), across both groups around 50 percent of teachers reported covering intended topics.

Table 1: Education systems with at least two content topics in each content domain, reporting ≥ 30 percentage point differences between the grade 8 intended and the enacted curricula

TOPIC	LOW-PERFORMING EDUCATION SYSTEMS	HIGH-PERFORMING EDUCATION SYSTEMS
Number	Chile, Iran, Jordan, Lebanon, Malaysia, Thailand	Chinese Taipei, England, Hong Kong, Hungary, Republic of Korea, United States
Algebra	Chile, Iran, Jordan, Lebanon, Malaysia, Thailand, Turkey	England, Hong Kong, Hungary, Japan, Republic of Korea, Singapore, United States
Geometry	Chile, Iran, Jordan, Lebanon, Malaysia, Thailand, Turkey	England, Hong Kong, Hungary, Republic of Korea, Singapore, United States
Data and chance	Iran, Jordan, Malaysia, Turkey	England, Hungary, Singapore

We compared intended and enacted instructional time by plotting the percentage of annual instructional time actually allocated to teaching mathematics against the corresponding curricular intentions for each education system (Figures 4 and 5), as well as determining national averages (Table 2). Although we observed considerable variation within groups, low-performing education systems, such as Chile, Lebanon and Iran, showed more variation in terms of the enacted instructional time. On average, the variation in the low-performing group was considerably greater than in high-performing education systems, indicating greater divergence from the intended curricula.

Figure 4: Time dedicated to mathematics instruction as a percentage of total annual instructional time in high-performing education systems

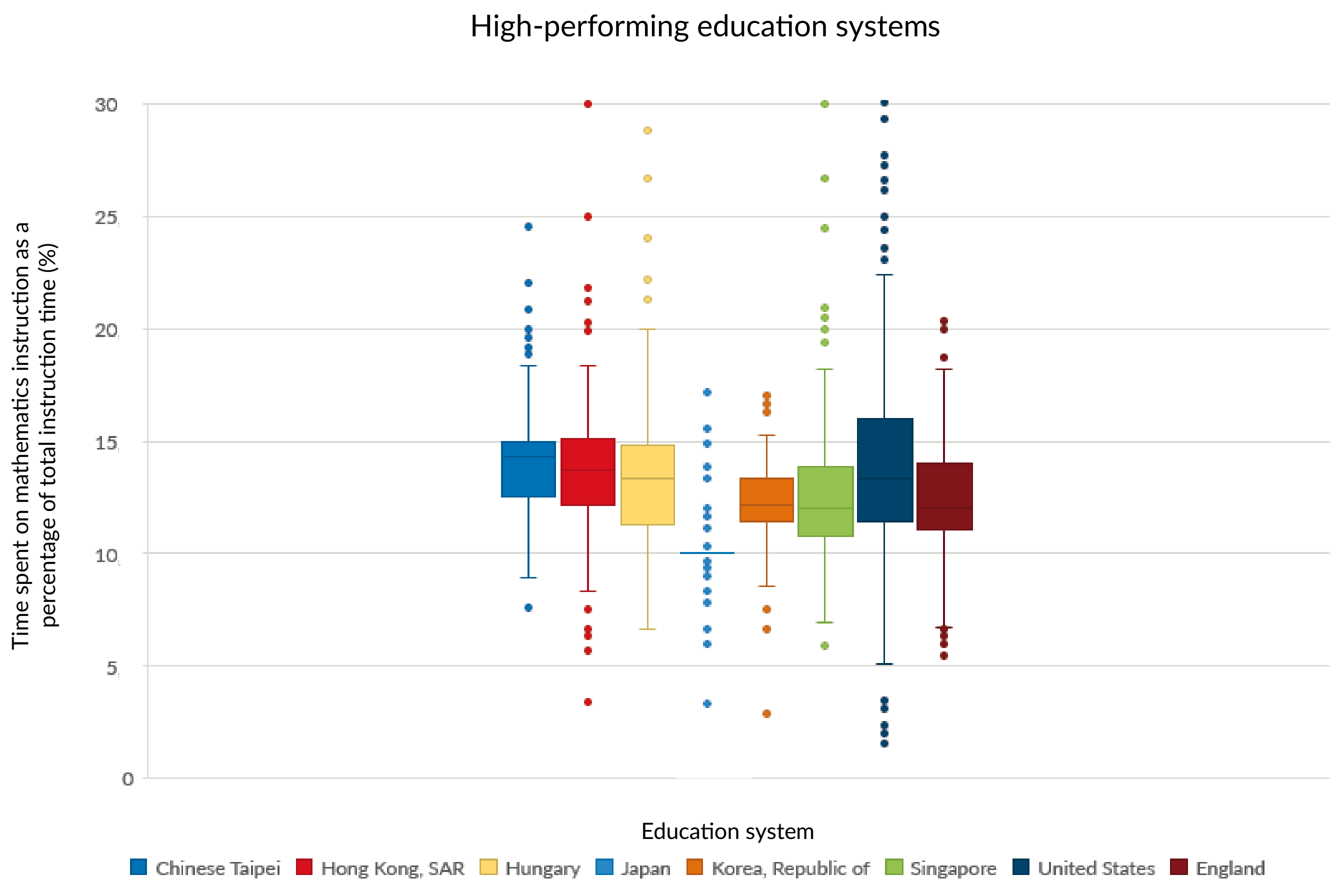


Figure 5: Time dedicated to mathematics instruction as a percentage of total annual instructional time in low-performing education systems

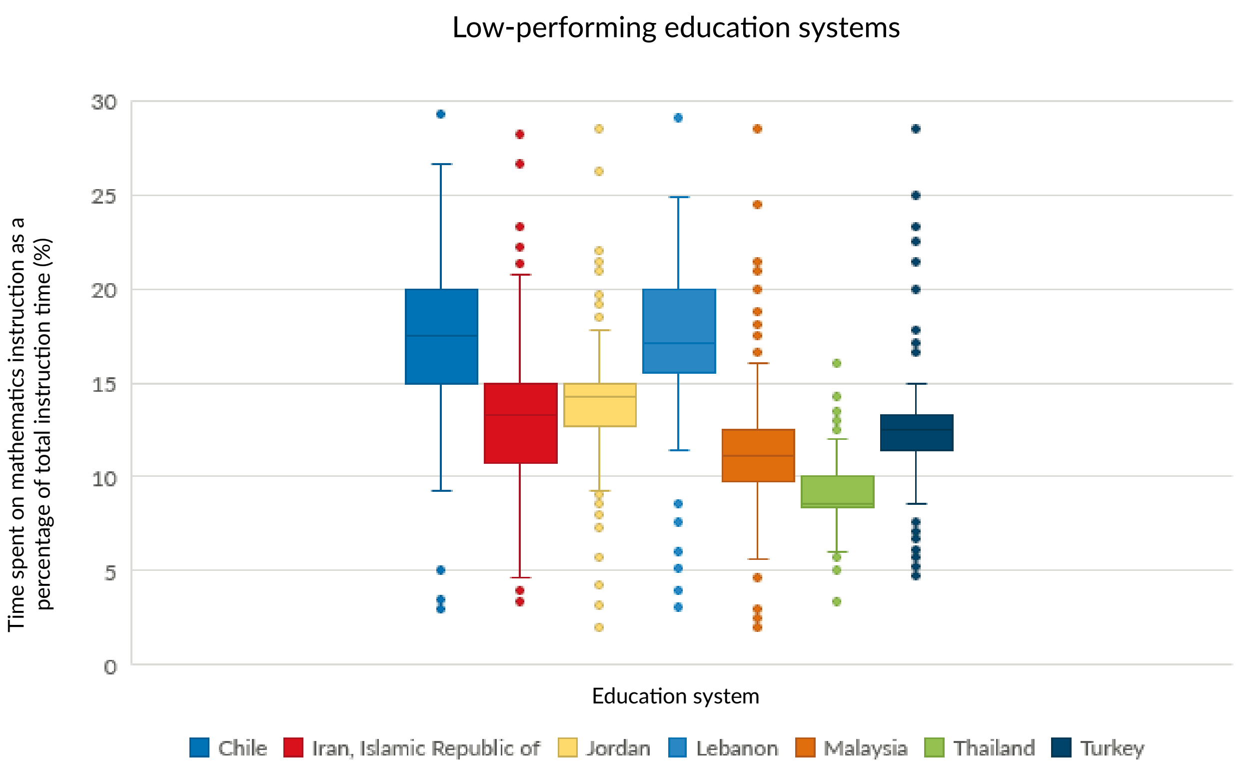


Table 2: Average intended versus enacted instructional time in low- and high-performing education systems

GROUP	EDUCATION SYSTEM	AVERAGE TIME SPENT ON MATHEMATICS INSTRUCTION AS A PERCENTAGE OF TOTAL INSTRUCTIONAL TIME (%)	AVERAGE TIME ALLOCATED TO MATHEMATICS INSTRUCTION AS A PERCENTAGE OF TOTAL INSTRUCTIONAL TIME (%)	AVERAGE VARIANCE WITHIN THE EDUCATION SYSTEM (%)
Low-performing education systems	Chile	16.6	12.0	16.5
	Iran	12.5	13.0	14.4
	Jordan	13.7	15.0	8.7
	Lebanon	16.7	16.0	17.3
	Malaysia	10.9	12.0	9.8
	Thailand	9.2	10.0	5.0
	Turkey	12.1	13.0	15.8
	Average	13.1	13.0	12.5
High-performing education systems	Chinese Taipei	14.2	12.5	6.2
	Hong Kong	13.8	13.5	7.6
	Hungary	13.3	12.5	8.4
	Japan	10.1	10.0	3.1
	Republic of Korea	12.1	11.0	3.0
	Singapore	12.3	15.5	6.5
	Average	12.6	12.5	5.8

We found that in both low- and high-performing education systems, teachers diverged considerably from the intended curriculum. However, some high-performing education systems, particularly Hong Kong, Japan, and the Republic of Korea, followed instructional time expectations more closely.

It is difficult to explain the low correspondence between intended and actual instructional time. It may be that teachers are exposed to more diverse student populations, and that teachers, as decision makers, thus adjust their instructional strategies to cover particular elements of the mathematics curriculum. It may be that schools reflect different local needs (for example, automatic progression, or low retention levels) and teachers are expected to provide the response. These, and other explanations, while plausible, merit further scrutiny.

CONCLUSIONS AND POLICY IMPLICATIONS

Our analyses have demonstrated that significant gaps exist between the intended and implemented grade 8 mathematics curriculum in many education systems, demonstrating considerable variation between official curricula and what teachers actually teach. These is true of both low- and high-performing education systems, and suggests that high-performance in mathematics is not necessarily dependent on teachers fully enacting or aligning their instruction according to the prescribed contents of the official curriculum, as many researchers and policymakers have assumed. Setting high standards for the overall national mathematics curriculum and ensuring that teacher adhere to these standards does not necessarily lead to higher learning.

The key challenge for education systems is to identify and foster conditions that enable teachers to better implement the intended mathematics curriculum. For example, this might encompass providing professional development opportunities so teachers can better assess and respond to student learning needs, or helping teachers to adapt their teaching strategies and available resources to achieve more meaningful instruction. Teacher policies regarding teacher supervision, mentoring, accountability, and evaluation, should also be aligned with this challenge in mind.

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FURTHER READING

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Aaron Benavot is Professor in the School of Education at the University at Albany- SUNY. His comparative education research focuses on the changing contours of primary and secondary education; global education policy, particularly in the areas of assessment and lifelong learning; and the interplay between education and sustainable development. During 2014-17, Dr Benavot served as director of the Global Education Monitoring Report (UNESCO, Paris), which monitors progress towards global targets in education, and produces independent research and analysis to support evidence-based policy making. Aaron has also co-authored or co-edited five books, including *PISA, Power, and Policy* and *School Knowledge for the Masses.*

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Treisy Romero-Celis completed her PhD in educational administration and policy studies at the University at Albany in 2017. She currently works at the National Institute of Educational Evaluation in Mexico developing recommendations to improve the instruction and professional development of teachers. Teacher policies, including teacher collaboration, professional development, and evaluation and the teaching of mathematics are some of her current research interests.

APPENDIX

DATA AND KEY MEASURES

We selected education systems that participated in three cycles of TIMSS (2007, 2011, and 2015) and that for two of three cycles had a grade 8 average mathematics score either significantly above or below the TIMSS scale center point. We also considered including education systems from different continents and selected those for which there was data for the variables used in the study. Fifteen countries met the criteria. These were categorized as low- and high-performing education systems. Education systems with average results significantly above the TIMSS scale center point (500 points) were categorized as high performing, while education systems with mean scores significantly below the international scale center point were categorized as low performing systems. The education systems that we included in our study were: Chinese Taipei, England, Hong Kong SAR, Hungary, Japan, thr Republic of Korea, Singapore, and the United States (the high-performing group), and Chile, Iran, Jordan, Lebanon, Malaysia, Thailand, and Turkey (the low-performing group).

National experts reported data for curricular intentions, while teachers reported information on the implemented curriculum (for further information on the TIMSS 2015 data please consult the IEA data repository, available open-access at www.iea.nl/data).

Content topics covered four domains: numbers, algebra, geometry, and data and chance. We analyzed a total of 20 subtopics within each of these domains.

Differences in the mean coverage of content topics and instructional strategies were tested using a Pearson chi-square test.

We used the following items to construct the instructional strategies variables:

- **LESS CHALLENGING INSTRUCTIONAL STRATEGIES (LCIS):** listening to the teacher explain new mathematics content; listening to the teacher explain how to solve problems; asking students to memorize rules, procedures and facts; and working on problems with the teacher's guidance.
- **MORE CHALLENGING INSTRUCTIONAL STRATEGIES (MCIS):** working on problems with the whole class and guidance from the teacher; relating the lesson to students' daily lives; asking the students to explain their answers; asking the students to complete challenging exercises that require them to go beyond the instruction; asking the students to decide their own problem solving procedures; and working on problems for which there is no immediately obvious method of solution.

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