For Official Use **EDU/EDPC(2016)13**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **02-May-2016**

English - Or. English

DIRECTORATE FOR EDUCATION AND SKILLS
EDUCATION POLICY COMMITTEE

EDU/EDPC(2016)13
For Official Use

Cancels & replaces the same document of 25 April 2016

3rd meeting of the Informal Working Group of the Future of Education and Skills: Education 2030

International Curriculum Analysis: Twenty Years of Background Analysing Mathematics and Science Curricula

3-4 May 2016
Paris, France

This paper has been drafted by William H. Schmidt, University of Michigan, as part of the background papers for the 3rd meeting of the Informal Working Group of the Future of Education and Skills: Education 2030, to be held on 3-4 May 2016.

Miho TAGUMA, Senior Analyst; E-mail: miho.taguma@oecd.org; tel.: +33-1 45 24 92 65
Shun SHIRAI, Analyst; E-mail: shun.shirai@oecd.org; tel.: +33-1 45 24 16 51
Katja ANGER, Consultant; E-mail: katja.anger@oecd.org; tel.: +33-1 71 37 42 37

JT03395135

English - Or. English

TABLE OF CONTENTS

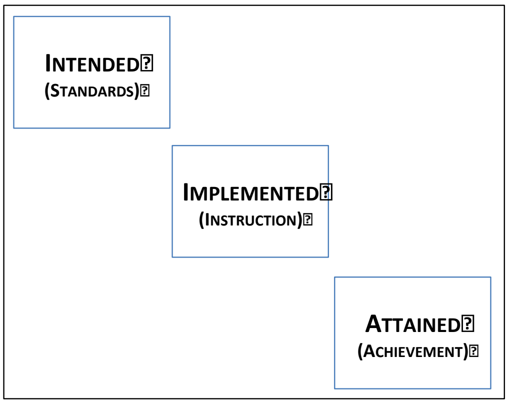
Figures

INTERNATIONAL CURRICULUM ANALYSIS: TWENTY YEARS OF BACKGROUND ANALYSING MATHEMATICS AND SCIENCE CURRICULA

What occurs in the classroom is ordinary and familiar. The result is dramatic. The cumulative effect of everyday classroom experiences is similar to that of falling snow. No single snowflake or lesson makes an obvious difference; the cumulative effect is undeniable. Further, as those who dwell in the colder regions can attest, "snow" is not simply "snow". Different types of snow yield qualitatively different effects. Tiny, dry, sparkling snow flakes can effortlessly be swept away. Large, moist, heavy flakes cling to branches and require great effort to move. Lessons similarly differ qualitatively in how curriculum and pedagogy are woven together in the classroom.[1]

1. In classrooms around the world curriculum and pedagogy come together to form experiences intended to foster and develop student understanding and mastery of subject matter. Most education research has focused on pedagogy and student outcomes while most education policy initiatives have focused on specifying the scope and content of the curriculum. In an effort to address this relatively less well-studied aspect of schooling — the content of the curriculum taught in mathematics and science classrooms — the 1995 Third International Mathematics and Science Study (TIMSS) included a major investigation of the curriculum intended for and implemented in the classrooms of over 40 countries.

Figure 1. Dimensions of Curriculum



Source: Schmidt et al., 1996.

2. The tripartite model of curriculum (Figure 1), conceptualised through earlier studies, was the foundation for all aspects of the 1995 TIMSS (Travers & Westbury, 1989; Schmidt et al., 1996). The model provides a conceptual map that links important aspects of the curriculum as it plays out in schools. The *intended* curriculum refers to the official expressions found in government documents that identify what students are expected to learn. Typically these are curriculum standards or guides published by education ministry departments or their equivalent. Textbook publishers often rely on these official documents to turn standards into lessons and accompanying exercises for students that may be used in classrooms. Teachers draw upon textbooks and other curricular resources to craft educational experiences for students. These classroom instructional experiences are referred to as the *implemented* curriculum. Finally, what students are able to demonstrate they have learned is referred to as the *attained* curriculum.

[1] Characterizing Pedagogical Flow: An Investigation of Mathematics and Science Teaching in Six Countries, Schmidt et al, 1996; page 2.

3. The key component in the examination of any single curriculum dimension — and an essential key in connecting any one dimension to any other — is the creation of a common language system that specifies subject matter content including the non-cognitive domains. Leading up to the 1995 TIMSS curriculum analysis, a multi-national research project, the Survey of Mathematics and Science Opportunities (SMSO), held multiple meetings with experts from multiple countries to draft two subject matter frameworks — one for mathematics, another for science — that would adequately and appropriately characterise the content of official curriculum documents such as curriculum guides, frameworks, and standards, published textbooks for use in classrooms, descriptions of the content teachers teach in their classrooms, as well as specifying the blueprints for the TIMSS student assessments (Survey of Mathematics and Science Opportunities, 1991a, 1991b, 1993; Schmidt et al., 1997b, 1997c). The resulting curriculum frameworks had categories to characterise three aspects: subject matter content, student performance expectations, and encouraged perspectives on the discipline. The five main performance expectations of the mathematics framework and the disciplinary perspectives bear close resemblance to current discussions around 21st century skills.

Curriculum Analysis Methods

4. In addition to the curriculum frameworks, SMSO also detailed the scientific analytic methodologies that would capture the substance of curriculum documents using a low-inference approach (Schmidt et al., 1997b, 1997c). These methods were similar for curriculum standards and textbooks. Documents were systematically catalogued and pedagogically relevant portions of each page were identified for coding which were then coded using the applicable TIMSS content framework. Native-language speakers in each country were trained to use the frameworks and analytic methods and experts from each country verified their country's data. Over 40 countries participated in the analyses of their mathematics and/or science curricula (see Appendix for list of countries). More recent work has augmented the frameworks to more fully characterise the advanced curricula in secondary mathematics and science and the analytic methods for coding have been streamlined significantly reducing the human resources required (Schiller et al., 2010; Schmidt & McKnight, 2012).

5. Another type of document analysis, referred to as "topic trace mapping", had curriculum experts in each participating country draw upon their knowledge of their country's curriculum standards or guides. The goal of this technique was to provide a concise picture of when topics were introduced, developed and focused on, and eventually dropped from the curriculum beginning in the primary grades and progressing through the lower secondary and upper secondary grades. This efficient resource methodology created curriculum portraits for each country that proved very fruitful in subsequent comparative and relational analyses (Schmidt et al., 1997b, 1997c: Appendix D).

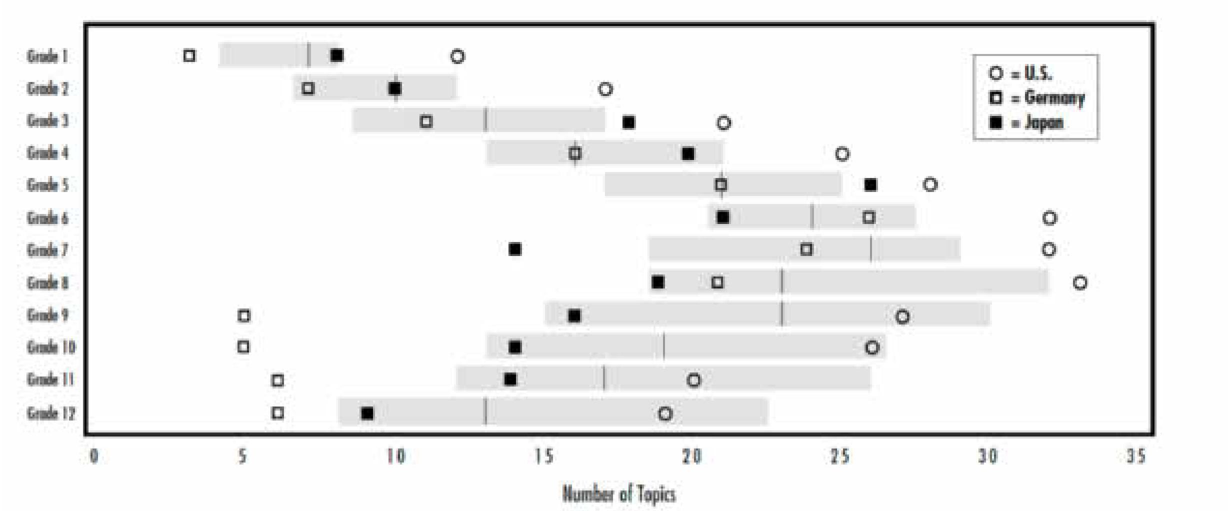
6. The 1995 TIMSS curriculum analysis also included an extended survey on curriculum decision-making that was completed by ministry level curriculum experts in each country. Questions exploring four key elements were included on the survey: goals for students; instructional content; methods of instruction; and the role of student examinations. Together these four elements provide a picture of the flow of curricular policy and its implementation that moved beyond simple dichotomous categories such as centralised or decentralised decision-making. (Schmidt et al., 2001, chapter 4).

7. As part of the main student assessment that occurred near the end of the academic year, teachers of students in grades 3, 4, 7, and 8 were given surveys and asked to indicate how many lessons they taught that focused on each of a grade-specific list of topics. The topics listed were grade-appropriate descriptions from the relevant TIMSS mathematics or science framework. These data yielded unique profiles of mathematics and science taught as reported by teachers in each country (Schmidt et al., 1999, 2001).

Illustration of Curriculum Analysis Results

8. Figure 2 is an example of the curricular insights relative to focus made possible from the international curriculum analysis of countries' content standards documents. The grey bars represent the range of number of topics intended to be taught by 50% of the countries at each grade; 25% of countries intended to teach more topics than the upper end of the grey bars; 25% of countries intended fewer topics than the lower end of the grey bar. The grey bars provide an international benchmark against which individual countries could examine their own curricular focus. The specific intentions for three countries are included as examples.

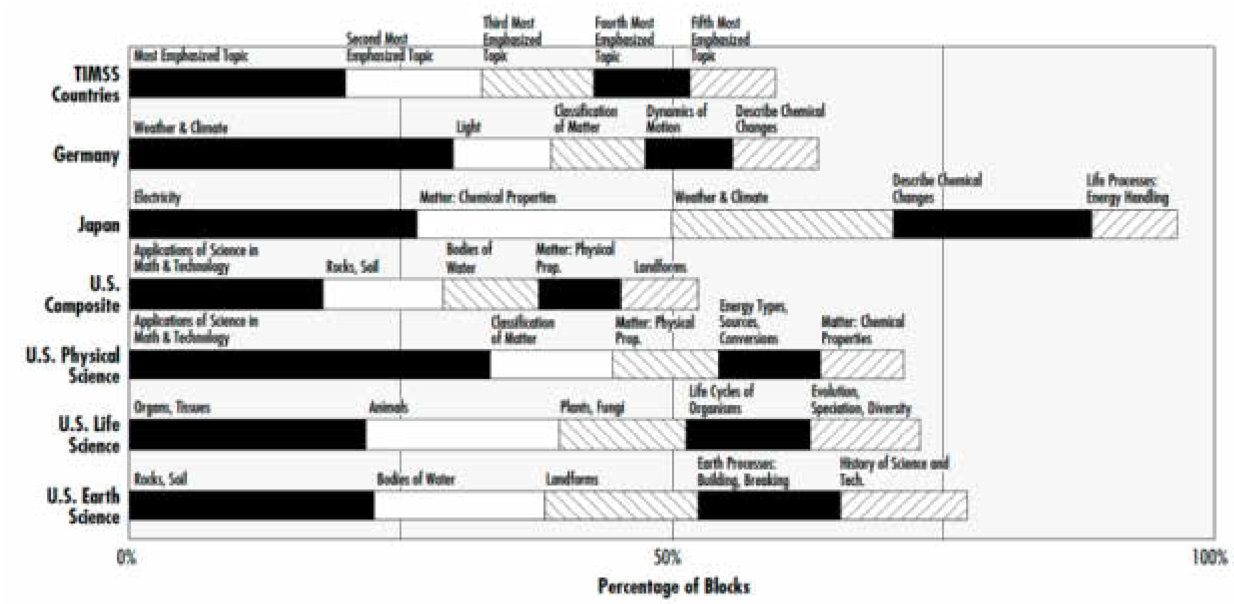
Figure 2. Number of mathematics topics intended across grades 1-12



Source: Schmidt et al. (1997), *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education*. Exhibit 1

9. Figure 3 illustrates the variation found among countries in the coverage of science topics as found in the textbooks for eighth grade students. A composite across all participating countries is identified illustrating that five topics typically represented about sixty percent of the material in the science curriculum. The textbooks from Germany and Japan found a greater proportion of the textbook dedicated to five topics while the U.S. demonstrated a more diluted emphasis. Note that the specific topics emphasised differed (Schmidt et al., 1997a: Exhibit 23). Comparing the U.S. to the international benchmarks available from the TIMSS curriculum analysis led to the characterization of the U.S. mathematics and science curricula being "a mile wide and an inch deep" (Schmidt et al., 1997a: page 62).

Figure 3. The five most emphasised topics in eighth-grade science



Source: Schmidt et al. (1997), *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education*

10. Subsequent analyses of the "topic trace maps" of the curricular intentions for the highest performing countries on the eighth grade TIMSS yielded a composite "A+" mathematics international benchmark (Figure 4). This led to the development of the concepts of coherence, focus, and rigor earlier referenced as important aspects of a curriculum (Valverde & Schmidt, 2000; Schmidt et al., 2005). Numerous countries in the revision of their standards have used these concepts.

Figure 4. The composite A+ mathematics international benchmark

Topic	Grade 1	2	3	4	5	6	7	8
Whole Number: Meaning	●	●	●	●	●			
Whole Number: Operations	●	●	●	●	●			
Measurement Units	●	●	●	●	●	●	●	
Common Fractions			●	●	●	●		
Equations & Formulas			●	●	●	●	●	●
Data Representation & Analysis			●	●	●	●		●
2-D Geometry: Basics			●	●	●	●	●	●
2-D Geometry: Polygons & Circles				●	●	●	●	●
Measurement: Perimeter, Area & Volume				●	●	●	●	●
Rounding & Significant Figures				●	●			
Estimating Computations				●	●	●		
Whole Numbers: Properties of Operations				●	●			
Estimating Quantity & Size				●	●			
Decimal Fractions				●	●	●		
Relation of Common & Decimal Fractions				●	●	●		
Properties of Common & Decimal Fractions					●	●		
Percentages					●	●		
Proportionality Concepts					●	●	●	●
Proportionality Problems					●	●	●	●
2-D Geometry: Coordinate Geometry					●	●	●	●
Geometry: Transformations						●	●	●
Negative Numbers, Integers, & Their Properties						●	●	
Number Theory							●	●
Exponents, Roots & Radicals							●	●
Exponents & Orders of Magnitude							●	●
Measurement: Estimation & Errors							●	
Constructions Using Straightedge & Compass							●	●
3-D Geometry							●	●
Geometry: Congruence & Similarity								●
Rational Numbers & Their Properties								●
Patterns, Relations & Functions								●
Proportionality: Slope & Trigonometry								●

Intended by more than half of the top-achieving countries ●

Source: Schmidt et al., 2005: simplified Figure 1, page 534.

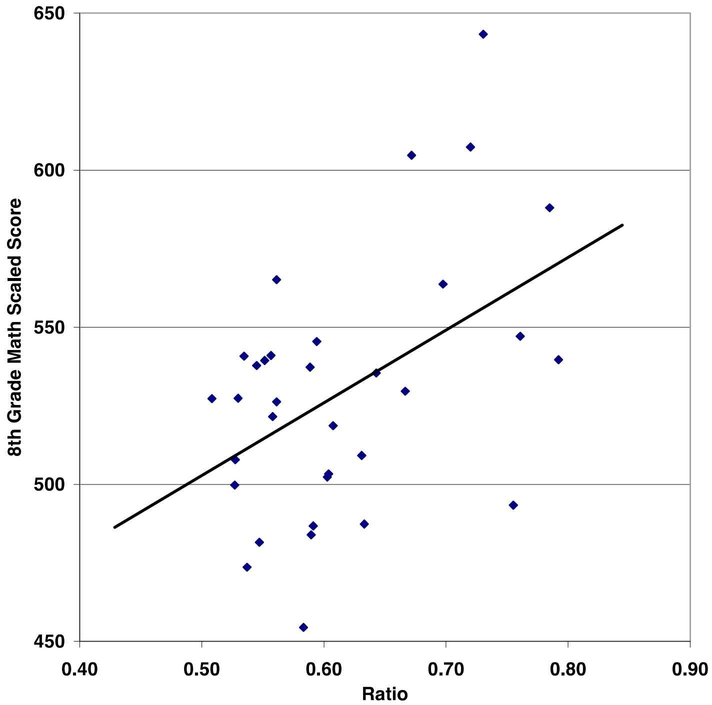
11. Briefly, these three important concepts about standards and curriculum more generally are defined as follows:

- Coherence — the manner in which curriculum topics enter, persist, and give way to more advance topics over the grades must reflect the logic of the academic discipline.
- Focus — given that instructional time in any one year is limited, the number of topics intended or implemented must be limited in order develop well those topics that are considered.
- Rigor — the selection of topics and their development is appropriately challenging at each grade and progresses from more basic concepts to more advanced ones across grades.

Curriculum Analysis Related to Student Performance

12. The portraits of curriculum generated through analyses of curriculum documents provide countries an opportunity to examine their own curricular intentions and practices against those of other countries. Examining what others do can be a helpful step in considering what changes or reforms might be entertained. Beyond such a stimulus to reform, the common sense notion that the curriculum — what a student studies and the time devoted to studying it — plays an important role in what a student learns and is able to do has been confirmed in analyses of both TIMSS and PISA data (Schmidt et al., 2001; Schmidt & Houang, 2007; OECD, 2014). For example, the aspects of coherence and focus deduced from countries' topic trace maps demonstrated a significant relationship with eighth grade students TIMSS mathematics performance (Figure 5).

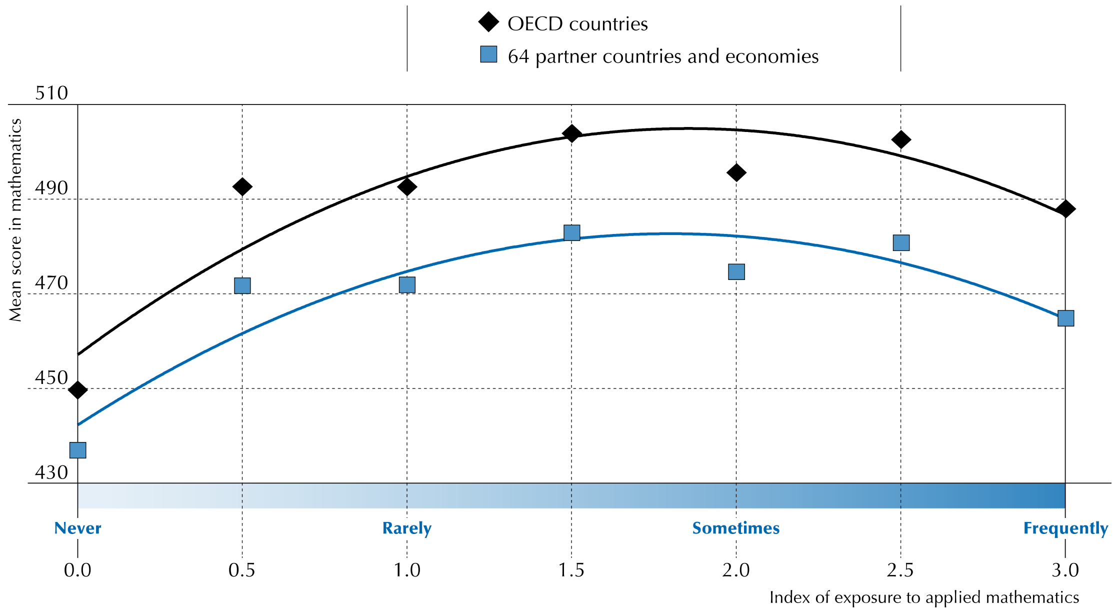
Figure 5. Plot of countries' TIMSS eighth grade mathematics scaled score versus the ratio of curricular coherence to focus



Source: Schmidt & Houang, 2007: page 80.

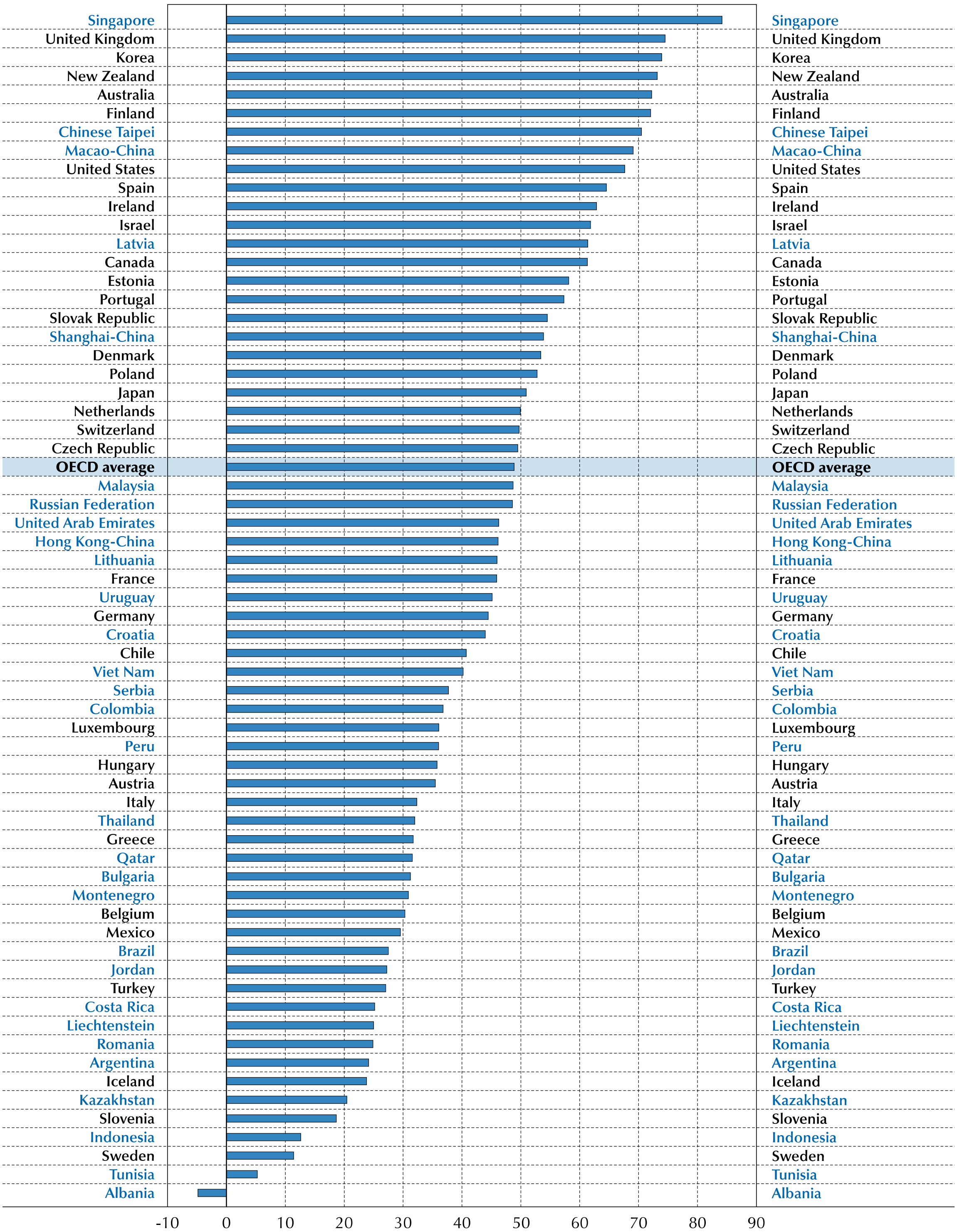
13. Yet more formal statistical analyses found significant relationships between the intended curriculum (standards/guides), the potentially implemented curriculum (textbooks), the implemented curriculum (instructional time) and student achievement. The significant structure of these relationships was found not to be the same for all countries (Schmidt et al., 2001). In other words, the policy environment within each country affected the nature of how curricular intentions, instruction, and student achievement were related. This can be seen in the recent PISA results relating two different types of curricular opportunities — formal and applied math — to the PISA literacy scores (see Figures 6-7). Figure 8 illustrates the great diversity among countries in how these two different types of curricular opportunities are related to one another. Other analyses have demonstrated that the variation of curriculum exposure within countries, i.e., variation in students learning opportunities, is related to how well students perform on related assessments (Schiller et al., 2010; Schmidt & Houang, 2007).

Figure 6. Relationship between mathematics performance and students' exposure to applied mathematics



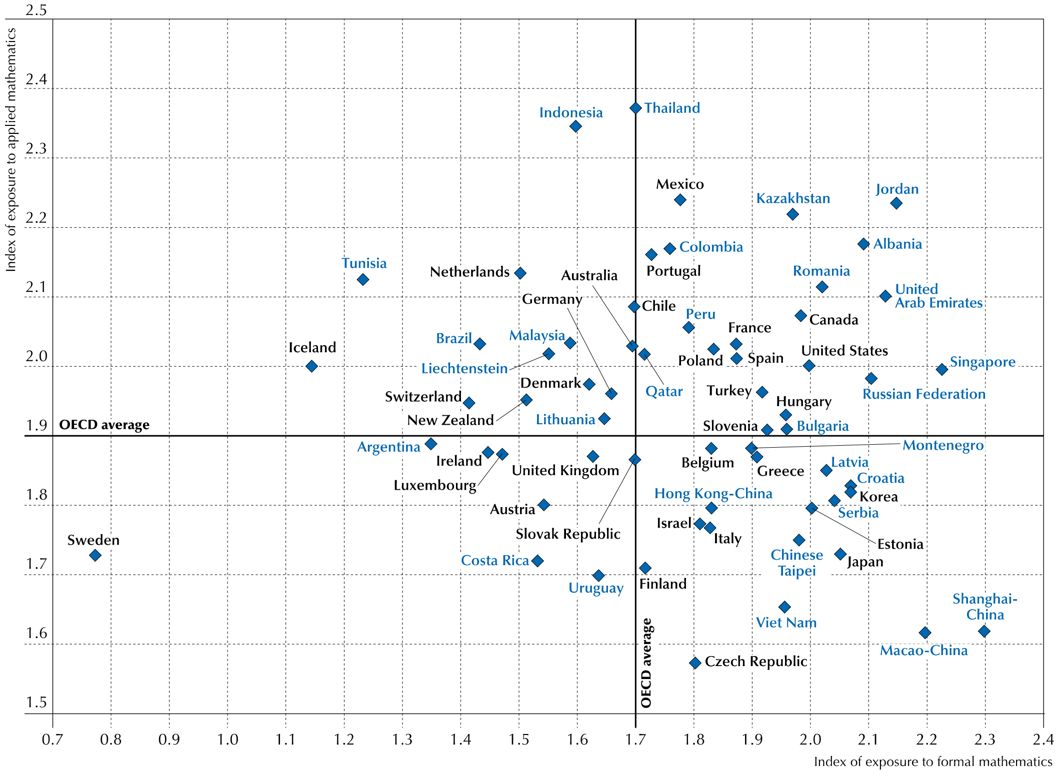
Source: Figure 1.3.2, OECD. (2014). *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science.*
1 2 http://dx.doi.org/10.1787/888932935591

Figure 7. Relationship between the index of exposure to formal mathematics and students' mathematics performance



Source: Figure I.3.4b,OECD. (2014). *PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science*,
1 2 http://dx.doi.org/10.1787/888932935591

Figure 8. Exposure to applied mathematics vs. exposure to formal mathematics



Source: Figure I.3.17, OECD. (2014). PISA 2012 Results: What Students Know and Can Do – Student Performance in Mathematics, Reading and Science.
1 2 http://dx.doi.org/10.1787/888932936427

An example of Curriculum Analysis Impacting Curriculum Policy

14. The goal of an international curriculum analysis is multifaceted. Although each participating country gains rich insight into their own curriculum the value of doing so as part of an international project is the potential to discern common and novel approaches that can then stimulate curriculum revision and reform discussions in each country.

15. For example, the United States' report developed from the 1995 TIMSS curriculum analysis on the U.S. mathematics and science curriculum concluded that they were “a mile wide and an inch deep” in comparison to the curricula in many other countries. In response, many states implemented standards for the first time or revised the ones that were in place. Although the state of Minnesota did have some curriculum guidelines in place, their participation in the 1995 TIMSS found that over half of their teachers were not familiar with the standards. Between Minnesota’s 1995 TIMSS participation and again in the 2007 TIMSS the state revised their mathematics standards twice and created articulated grade-by-grade science standards for the first time. Michigan and several other states revised their grade-ban standards and created grade-by-grade standards making it clear which topics were to be the focus of the curriculum each year. Michigan and Massachusetts consulted the A+ international mathematics benchmark that was developed from the 1995 curriculum analysis in revising their mathematics standards in order to bring greater coherence and focus to their revised standards. Finally, the National Governors Association decided to partner with a business organization to sponsor the drafting of a set of 21st century mathematics standards that would embody the concepts of coherence, focus, and rigor (Schmidt et al., 1997a, 1997b).

REFERENCES

Common Core State Standards Initiative 2010. Common Core State Standards for Mathematics. National Governors Association Center for Best Practices (NGA Center) and the Council of Chief State School Officers (CCSSO).

OECD. (2014), *PISA 2012 Results: What Students Know and Can Do (Volume I, Revised edition, February 2014): Student Performance in Mathematics, Reading and Science*, PISA, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/9789264208780-en

Schiller, K. S., Schmidt, W. H., Muller, C. & Houang, R. T. 2010. Hidden Disparities: How Courses and Curricula Shape Opportunities in Mathematics During High School. *Equity & Excellence in Education*, 43**,** 414-433.

Schmidt, W. H., Jorde, D., Cogan, L. S., Barrier, E., Gonzalo, I., Moser, U., Shimizu, K., Sawada, T., Valverde, G., Mcknight, C., Prawat, R., Wiley, D. E., Raizen, S., Britton, E. D. & Wolfe, R. G. 1996. *Characterizing Pedagogical Flow: An Investigation of Mathematics and Science Teaching in Six Countries,* Dordrecht/Boston/London, Kluwer.

Schmidt, W. H., Mcknight, C. & Raizen, S. 1997a. *A Splintered Vision: An Investigation of U.S. Science and Mathematics Education,* Dordrecht/Boston/London, Kluwer.

Schmidt, W. H., Mcknight, C., Valverde, G. A., Houang, R. T. & Wiley, D. E. 1997b. *Many Visions, Many Aims, Volume I: A Cross-National Investigation of Curricular Intentions in School Mathematics,* Dordrecht/Boston/London, Kluwer.

Schmidt, W. H., Raizen, S. A., Britton, E. D., Bianchi, L. J. & Wolfe, r. G. 1997c. *Many Visions, Many Aims, Volume II: A Cross-National Investigation of Curricular Intentions in School Science,* Dordrecht/Boston/London, Kluwer.

Schmidt, W. H., Mcknight, C., Cogan, L. S., Jakwerth, P. M. & Houang, R. T. 1999. *Facing the Consequences: Using TIMSS for a Closer Look at U.S. Mathematics and Science Education,* Dordrecht/Boston/London, Kluwer.

Schmidt, W. H., Mcknight, C. C., Houang, R. T., Wang, H. A., Wiley, D. E., Cogan, L. S. & Wolfe, R. G. 2001. *Why Schools Matter: A Cross-National Comparison of Curriculum and Learning,* San Francisco, Jossey-Bass.

Schmidt, W. H., Wang, H. A. & Mcknight, c. C. 2005. Curriculum Coherence: An Examination of US Mathematics and Science Content Standards From An International Perspective. *Journal of Curriculum Studies*, 37**,** 525-529.

Schmidt, W. H. & Houang, R. 2007. Lack of Focus in the Mathematics Curriculum: Symptom or Cause? *In:* LOVELESS, T. (ed.) *Lessons Learned: What International Assessments Tell Us about Math Achievement.* Washington, DC: Brookings Press.

Schmidt, W. H. & Mcknight, C. C. 2012. *Inequality for all: The challenge of unequal opportunity in American schools,* New York, NY, Teachers College Press.

Survey of Mathematics and Science Opportunities (SMSO) 1991a. Mathematics Curriculum Framework. East Lansing: Michigan State University.

Survey of Mathematics and Science Opportunities 1991b. Science Curriculum Framework. East Lansing: Michigan State University.

Survey of Mathematics and Science Opportunities 1993. A description of the TIMSS' achievement test content design: test blueprints. East Lansing: Michigan State University.

Travers, K. J. & westbury, I. 1989. *The IEA Study of Mathematics I: Analysis of mathematics curricula,* Oxford, England, Pergamon Press.

Valverde, G. A. & Schmidt, W. H. 2000. Greater expectations: learning from other nations in the quest for 'world-class standards' in US school mathematics and science. *Journal of Curriculum Studies,* 32**,** 651-687.

APPENDIX

Countries Participating in the 1995 TIMSS Curriculum Analysis

Argentina
Australia
Austria
Belgium
Bulgaria
Canada
China, People's Republic of
Colombia
Cyprus[2 3]
Czech Republic
Denmark
Dominican Republic
France
Germany
Greece
Hong Kong
Hungary
Iceland
Iran
Ireland, Republic of
Israel
Italy
Japan
Korea
Latvia
Lithuania
Mexico
Netherlands
New Zealand
Norway
Philippines
Portugal
Romania
Russian Federation
Scotland
Singapore
Slovak Republic
Slovenia
South Africa
Spain
Sweden
Switzerland
Thailand
Tunisia
United States

Source: Schmidt, W. H., Mcknight, C., Valverde, G. A., Houang, R. T. & Wiley, D. E. 1997a. *Many Visions, Many Aims, Volume I: A Cross-National Investigation of Curricular Intentions in School Mathematics,* Dordrecht/Boston/London, Kluwer.

[2] Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

[3] Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.