Chapter 22
Impacts of TIMSS and PISA on Mathematics Curriculum Reforms

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The results of international experience and research in the teaching and learning of mathematics, on a global level, have influenced school mathematics curriculum with the emergence of a relatively uniform mathematics curriculum, comprising an internationally accepted core of mathematical knowledge and skills (e.g. Cai & Howson, 2013). From a distance, this perspective has some footing since it regards common topics and notions as they might be presented within national curriculum documents. However, such 'zooming out' may ignore cultural factors and local conditions, including teaching practices, classroom norms, and assessment methods. These forms of variation need closer scrutiny (e.g. Hiebert et al., 2003; Guberman & Abu Amra, 2018).

Considerable variations are also found when specific curriculum issues are considered. For example, within the mathematics curriculum for basic education in many countries, the topic of Statistics focuses on describing, representing, and interpreting data (e.g. Biehler et al., 2018), but there are considerable differences in how statistical content is approached, especially through the use of technology and real-world data (e.g. Ben-Zvi et al., 2018). Furthermore, the ways in which mathematical literacy or computational/algorithmic thinking are defined and included in

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the school curriculum show no consistent pattern of how these notions have been integrated in the school mathematics curriculum (see Goos & O'Sullivan, 2018; Rafiepour, 2018; Stephens, 2018). These curriculum issues are further examined in the accompanying chapters of theme *Globalisation and Internationalisation, and their impacts on mathematics curriculum reforms*.

Among the most important drivers of curriculum reform are probably international assessment studies, which are complex educational products resulting from the processes of globalisation and internationalisation.[1] These studies have contributed to curriculum changes in the following way: they first draw attention to certain aspects of curriculum that need improvement; these aspects are then often improved though the recognition and application of some components of these studies.

By focusing on question "How have international studies driven school mathematics curriculum reforms?", this chapter examines the role of international studies TIMSS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) as global drivers for these reforms. Their influences are discussed both worldwide and in individual countries, with an emphasis on the application of particular components in (re)designing and implementing curriculum improvements. Examination of these influences is important in helping educators better understand global trends and their implications for teaching and learning mathematics.

In the remaining part of this chapter, global influences of TIMSS and PISA are examined first. This is followed by four case studies from economically and geographically diverse countries. The chapter ends with a critical summary of the findings presented and outlines directions for further research.

Global Influences of TIMSS and PISA

The section presents the influences of these two international studies worldwide. TIMSS influences are mostly related to a certain curricular convergence regarding topics to cover and skills to foster, whereas PISA influences primarily concern the inclusion of the notion of mathematical literacy in curricula, which is usually expressed in terms of competencies or capabilities.

[1] The principal characteristics of these processes have been outlined in the Introduction of theme D *Globalisation and internationalisation, and their impacts on mathematics curriculum reforms*. The components of each international assessment study have been influenced by trans-national processes of diverse nature (economic, social, educational, cultural, political) resulting from international actions by various national and international agencies and institutions that strive for concrete economic, social, educational, cultural, and political benefits. Beside such an outward direction, these actions are also directed inwardly through, as Cai and Howson (2013) underlined, adapting globally developed educational products (i.e. assessment packages) to particular countries' needs.

TIMSS Influences

Since 1995, TIMSS has provided data on fourth- and eighth-grade students' achievements in mathematics and science for more than 50 countries worldwide, every 4 years (see https://timss.bc.edu/). Apart from reported achievement data, TIMSS international databases contain the values of many contextual variables, used to explain differences in students' achievements within and among countries, resulting in a great number of secondary analyses. The outcomes of primary and secondary TIMSS research have influenced the development and (re)design of mathematics and science education curricula across the world. The first curricular changes, starting at the end of 1990s, were described in Robitaille et al. (2000). Recent twenty-first-century changes are documented in TIMSS Encyclopedias (e.g. Mullis et al., 2016c).

During the first 20 years of TIMSS studies, most participating countries have implemented reforms to their mathematical curricula, ranging from updates to detailed revisions, by using TIMSS results to review their curricula and improve them (Mullis et al., 2016b). Despite countries differing in many respects (e.g. economical, geographical, religious), their curricula have become increasingly similar, organised around common broad content areas (e.g. number) expressed in terms of their sub-topics (e.g. fractions and decimals). Furthermore, many emphasise the role of problem solving and thinking skills, such as applying mathematics and mathematical reasoning. These researchers therefore argue that TIMSS has brought a certain curricular convergence worldwide regarding topics to cover and skills to foster. This outcome, as put forward by authors participating in the TIMSS project, may be accepted with caution, but a more uniform international mathematics curriculum does seem to have emerged (e.g. Cai & Howson, 2013) although it has not been established what could constitute the details of such a curriculum.

The impact of TIMSS results on curricular and related issues in particular countries is summarised in TIMSS 2015 Encyclopaedia (Mullis et al., 2016c): each country report includes a section "Use and impact of TIMSS", and some describe that impact in a detailed way. An examination of these reports for about 60 countries that participated in TIMSS 2015 revealed that, apart from the influence on curricular reforms in many participating countries, results have also influenced teacher professional development and national assessments. Because some country reports are unclear about all areas of impact, the number of countries implementing substantial change can only be estimated, with at least one-third regarding teacher professional development and one-fifth concerning national assessments.

Having in mind the distinction underlined by Mullis and colleagues (2016c) between intended, implemented and attained curriculum, i.e. between what is expected to be taught, what is actually taught, and what is learned, TIMSS appears to have a dominating influence on intended curriculum. However, its influence on teacher professional development and national assessments clearly relates to implemented and attained curricula. Knowing that teachers' professional development is highly relevant to implemented and attained curricula, it is surprising that the double impact of TIMSS results on curricular reforms *and* teacher professional development, as documented in the 2015 Encyclopaedia, was found in just one-fifth of TIMSS countries represented there. An examination of the section "Use and impact of TIMSS" in the latest TIMSS Encyclopedia for the 2019 project cycle (Kelly et al., 2020), which became available after the first version of this chapter was completed, might reveal similar figures regarding the most recent worldwide impact of TIMSS on curricular reforms, teacher professional development, and national assessments.

Since 2019, an eTIMSS study has been offered in digital format. This change has required the inclusion of innovative problem solving and inquiry tasks that simulate real world situations, whose solutions may be found through the applications of interactive scenarios (Mullis & Martin 2017). These tasks certainty call for new competencies, including computational thinking – a distinctive way of thinking applied while working with problem solutions expressed in representations that could be efficiently processed by technology (e.g. Wing, 2011).

PISA Influences

The Organisation for Economic Co-operation and Development (OECD) launched PISA in 2000 to assess basic competencies in reading, mathematics, and science of 15-year-olds students every 3 years, focusing on mathematics in 2003 and 2012. Apart from these three core subjects, PISA 2018, administered in all OECD member countries and many other countries worldwide (almost 80 countries in total), involved the assessment of two domains, namely: financial literacy and global competence (see: http://www.oecd.org/pisa/).

Like TIMSS, PISA international databases contain the values of many contextual variables, used to explain differences in students' achievements within and among countries, resulting in many secondary analyses. Although PISA research has influenced policy reforms in a number of countries (e.g. Breakspear, 2012), Lingard (2017) and some others claim that PISA primary outcomes in terms of national scores and rankings, rather than its secondary analyses, have been used to initiate and justify curricular reforms. This may also hold true for TIMSS research, but such a conclusion has not been reported so far in the literature, to the authors' knowledge.

Unlike TIMSS, which has assessed students' mathematical knowledge mostly by using traditional school tasks, PISA has assessed students' mathematical literacy (in terms of a matrix of mathematical capabilities by mathematical processes) for several domains and different task contexts (e.g. OECD, 2019), by using tasks mostly related to real-world situations. The use of such tasks – unfamiliar to many students, especially in the first cycles of PISA – has contributed to low or unsatisfactory students' results in many countries. This caused the so-called "PISA shocks" in countries such as Germany and Japan. Consequently, many countries have begun to use PISA-like tasks in their national assessments (Lingard, 2017), which may be considered as one kind of PISA influence on mathematics curriculum. However, over-use of such tasks may not be desirable. While modelling and applications are important components of mathematics education, so are proofs and mathematical structures. Moreover, the difficulty of such tasks may be more affected by the complexity of the contexts used than the mathematics involved in solving them (Stacey et al., 2015).

Whereas the influence of TIMSS on mathematics and science curricula worldwide has been officially documented in TIMSS Encyclopaedias (e.g. Mullis et al. 2016c), few OECD documents have examined the influence of PISA research on national policy reforms. Breakspear (2012), however, using National PISA Reports, showed that PISA had, in varying ways and extents, been embedded in national policies in the majority of countries via performance targets, curriculum standards or assessment practice. However, of the existence of competing policy drivers, such as the recommendations and benchmarks of the European Union (EU), including key competencies of lifelong learning (Michel, 2017) makes it difficult to determine how much these effects can be attributed directly to PISA.

A recent systematic review of research articles on PISA revealed that articles dealing with impact/policy had rarely addressed its impact on the curriculum (Hopfenbeck et al., 2018). An exception is the study of Stacey et al. (2015), which examined PISA influence on mathematics education in ten countries worldwide. This study showed that PISA has influenced mathematics curricula in the majority of these countries. This was done by applying the PISA notion of mathematical literacy, usually expressed in terms of competencies or capabilities. While national assessments have been influenced by PISA framework in Chile and Spain, PISA tasks have been used for formative assessment in Denmark or adapted to meet official standards in France. Stacey et al. (2015) showed that support for PISA-related curricular changes, implemented through teacher professional development, was evident in only a few countries, such as Denmark and Israel. Appropriate teacher professional development promoting such a practice is thus needed, especially when technology is applied in the classroom (e.g. Drijvers et al., 2016).

The framework for mathematical literacy for PISA 2021 study includes Computational thinking (OECD, 2018). Its inclusion into the school mathematics curriculum, is examined in other chapters of theme *Globalisation and Internationalisation, and their impacts on mathematics curriculum reforms*.

Particular Influences of TIMSS and PISA

The particular influences of TIMSS and PISA presented in this section were selected by applying two criteria: countries that are economically and geographically diverse. This selection resulted in four countries from different continents: Australia, Israel, Mexico, and Serbia. Australia and Israel are countries with high-income economies, whereas Mexico and Serbia are countries with middle-income economies, according to the World Bank list of economies, June 2019.

The case study from Mexico examines the influence of PISA, whereas the case studies from Israel and Serbia summarise the influence of TIMSS. The influence of both studies is presented in the case study from Australia.

Australia

The Australian Curriculum: Mathematics (AC:M; ACARA, 2018) is arranged in three content, and four proficiency strands. The content strands – number and algebra; measurement and geometry; statistics and probability – represent, according to Sullivan (2018) a "conventional statement [...] of the focus of the curriculums worldwide" (p. 90). This focus is mirrored in the content areas used by TIMSS. The adoption of the AC:M by the all Australian States and Territories from 2014 has provided a framework for Australia's National Assessment Program – Literacy and Numeracy (NAPLAN) and including the use of a calculator-active component of NAPLAN.

The *proficiency* or process strands of the AC:M reflect the language of capabilities and competencies which have become part of PISA and PIAAC. Sullivan (2018) points out that the elaborations of the proficiencies in the AC:M were based on the recommendations of Kilpatrick, Swafford and Findell (2001). The first proficiency is understanding (Kilpatrick et al.'s term was *conceptual understanding*), and the second proficiency is fluency (*procedural fluency*). A third proficiency strand, problem solving (*strategic competence)*, is described as:

> the ability to make choices, interpret, *formulate*, model and investigate problem situations, and communicate solutions effectively. Students *formulate and solve problems* when they use mathematics to represent unfamiliar or meaningful situations, when they design investigations and plan their approaches, when they apply their existing strategies to seek solutions, and when they verify (*evaluate*) their answers (*results*) are reasonable. (quoted from ACARA, 2018, by Sullivan, 2018, p. 90)

The fourth proficiency, reasoning (*adaptive reasoning*) includes:

> analysing, proving, *evaluating*, explaining, inferring, justifying and generalising. Students are reasoning mathematically when they explain their thinking, when they deduce and justify strategies used and conclusions reached, when they adapt the known to the unknown, when they transfer learning from *one context to another*, when they prove that something is true or false and when they compare and contrast related ideas and explain their choices. (quoted from ACARA, 2018, by Sullivan, 2018, p. 90)

Parallels between these two proficiencies, as expressed in the AC:M and in the PISA 2012 Mathematics Framework (OECD, 2013), are shown in Fig. 22.1 by key words in common, such as *formulate*, *evaluate*, and *context* – given above.

One important consequence of the PISA Framework (OECD, 2013) has been the development of several national projects to build teachers' capacity to implement these proficiencies in classrooms and to engage in rigorous professional learning, introducing serious mathematical topics in a spirit of inquiry, embodying high levels of mathematical reasoning and problem solving.

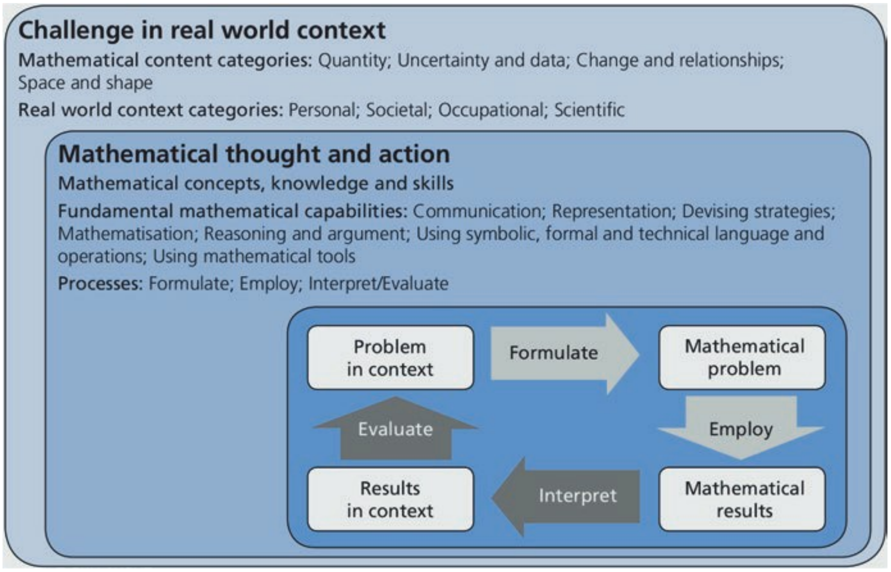

Fig. 22.1 A model of mathematical literacy in practice (OECD, 2013, p. 26)

One such program, *reSolve – Promoting a spirit of inquiry* (https://www.resolve.edu.au) – was funded by the Australian government as a collaboration between Australian Academy of Science and the Australian Association of Mathematics Teachers. The *reSolve* program includes classroom resources for teachers from Foundation Year (K) to Year 10, professional learning modules, and special topics. Many *reSolve* special topics embody resources that address the needs of twenty-first century learners of mathematics following the key elements of the PISA Mathematics Framework, including opportunities for using new technologies in real world contexts.

As stated above, the TIMSS model of diagnostic assessment has been powerful in providing the model for Australia's national assessment program – literacy and numeracy (NAPLAN) which is currently conducted in all schools in Years 3, 5, 7 and 9. However, the need for some reform of NAPLAN has been highlighted in recent debate on whether an exclusive focus on literacy and numeracy might need to be expanded in the future to better serve Australia's schools and young people. This debate is summarised in a 2019 NAPLAN Review Interim Report (McGaw et al., 2019). Unlike TIMSS, NAPLAN occupies considerable school, teacher, and community attention, and so fosters an impression that other areas of thinking (e.g. STEM literacy, critical and computational thinking) may be secondary, and possibly optional.

What can be learned from the case study from Australia? There, TIMSS and PISA occupy an important role as international benchmarks of performance. Their reports now show that Australia's once strong rankings are falling. TIMSS has provided a model for the design Australia's annual assessment of numeracy through

NAPLAN. Growing societal concerns for fostering a wider range of competencies among school students suggest that the TIMSS model may need an overhaul. PISA, on the other hand, appears more responsive to these concerns with its greater emphasis on STEM-literacy and critical thinking.

Israel

The results of the TIMSS-1999 study were a starting point for significant changes in the Israeli mathematics curriculum for all ages. The main change is reflected in the coverage of the mathematical content for secondary schools: in 1999 the coverage rate was 41%; in 2011 it reached 100% (RAMA, 2011). The curriculum change included the addition of mathematical topics and thinking skills, previously not there before (Feniger, 2020). In addition, the study makes it possible to compare the achievements of different groups in the country's education system. The results of the TIMSS-2011 tests showed, for example, that the distribution of student achievements in mathematics in Israel is the largest among countries with high or similar achievements (Mullis et al., 2012).

In order to assist students at 'both ends' in mathematics, thus maximising the ability of those who have difficulties and promoting outstanding students, the "Mitzui–Metzuyanut in Mathematics" program was implemented in Israel. This program included students with difficulties that had potential, whom the schools defined as students who without support might drop out of mathematics studies. The 'Metzuyanut' program included students with interest, motivation and high ability in mathematics (Zaslavsky et al., 2018). The two groups of students studied in separate classes, with appropriate learning methods: the 'Mitzui' groups (grades 7–9) studied the standard 5 h of mathematics per week in a group separated from their regular class. The 'Metzuyanut' group, on the other hand, received an additional one to 2 h of enrichment in mathematics. These programs included a complete layout for their operation: teacher-training courses, unified seminars for teachers from different sectors, tools for locating suitable students, evaluation and monitoring systems of students' progress, and more.

As a result of the implementation of this program, the rate of high-achievers' students increased slightly: from 12% in 2011 to 13% in 2015. This figure places Israel in eighth place in terms of the percentage of outstanding students. Also, compared to countries that are similar in average to their achievements in mathematics, in Israel the percentage of outstanding students is the highest. Unfortunately, despite this program, the rate of low-achiever students increased from 13% in 2011 to 16% in 2015. There are several reasons for this. The first is the division of students into groups according to learning levels from the age of thirteen with almost no possibility of moving from one level to another, especially in the Arabic-speaking sector (Razer et al., 2018).

Another reason, according to findings by the State Comptroller's Office, is that about one-fifth of students experiencing difficulty do not receive additional math study hours in mathematics to which they have been assigned by the Ministry of Education (The State Comptroller of Israel, 2014). Furthermore, teachers who teach in the 'Mitzui' program have less training than the teachers in higher levels (Arcavi & Mandel-Levi, 2014). These changes have led to an even greater difference among Israeli students: The dispersion remains high and there was also a slight increase of eight points in the distribution of scores (Mullis et al., 2016b). The conclusions of the Israeli Ministry of Education following the TIMSS-2015 test indicate that gaps between the sectors must be taken into consideration, and this domain is currently undergoing treatment (The Ministry of Education, 2016).

What can be learned from the Israeli case study? It is important to narrow the gap between low-achieving and high-achieving students, and different approaches should be applied. To this end, the Ministry of Education is working on several projects: new mathematics curricula for lower levels with an emphasis on the relevance of mathematics to daily life; a national Virtual High School where, in addition to their schooling, students from different corners of the country can learn together in a meaningful way; and new professional development of teachers, enabling them to work more effectively with students of different abilities.

Mexico

A comparative analysis of the curricula in Mexico, Chile, South Korea and England was initiated by the National Institute for the Evaluation of Education (INEE) and published in Rojano and Solares-Rojas (2017). It found that, in broad terms, the Mexican curriculum shares with the other countries an important nucleus of mathematical content and common characteristics of its design. The development of competences, problem solving, mathematics in context and the influence of education research reflects a global tendency in line with the PISA assessment program.

PISA exercised an explicit and strong influence on the Mexican curriculum on both previous and current curricular designs (SEP, 2011a, 2017; INEE, 2018). For instance, the 2011 Mexican program of studies asks:

> In its vision towards 2021, the curriculum should lay the foundations of average Mexican society acquisition of the general competences currently shown by level 3 of PISA; eliminating the gap of Mexican children currently located below level 2, and strongly supporting those who are in level 2 and above. The reason for this policy must be understood from the need to drive with determination, from the education sector, the country towards the knowledge society. (SEP, 2011a, p. 85; *translated by Armando Solares-Rojas*)

In Mexico, PISA has produced both positive and undesirable effects (Rojano & Solares-Rojas, 2017, 2018). On the one hand, Mexican curricular design follows an international trend regarding the development of competences, taking into account the impact of local contexts and the conditions where learning takes place. On the other hand, there were some conflicts in the way competences are included in Mexican program of studies; for instance, at the same time the program uses both mathematical competences and content descriptors as leading criteria for the definition and the organisation of the mathematics that students should learn. Moreover, the contents are organised not only by content blocks (defined bimonthly), but also by content themes or ‘axes’ (applied to each block). The resulting knowledge segmentation can generate discontinuities in the development of mathematical ideas.

To illustrate this discontinuity, we refer to the curriculum of grade 6 which consists of five blocks and three themes, namely: number sense and algebraic thinking; form, space, and measurement; data management. The topic of volume is first studied in Block 3 through comparing the volumes of bodies without using standard units, whereas, 2 months later, in Block 4, the use of cubes as standard units to calculate volumes is introduced (SEP, 2011b). After starting the study of volumes at Block 3, students have to switch to contents of other thematic axes (e.g. to data management at the end of this block). Then, at the beginning of Block 4, they first have to study contents dealing with number sense and algebraic thinking. Only in the middle of Block 4 do students return to study the volume of geometric bodies.

This segmentation by time and thematic axes can not only generate discontinuity in the development of some mathematical notions, it also prescribes rigid teaching times that do not consider the real, diverse and varied needs of the classrooms. Rojano and Solares-Rojas (2017) provide supporting evidence of these issues and propose concrete aspects to be considered in new reforms of Mexican curriculum.

What can be learned from the case study from Mexico? To improve mathematics education, curricular redesign should address not just international trends but also a number of critical issues, such as making clear and explicit the purpose of teaching mathematics to every citizen, explicating the findings of research in mathematics education being applied, and incorporating the teacher’s perspective to give flexibility for teachers to adapt the curricular design to their specific classrooms and local contexts. Such an approach would avoid or reduce various content and pedagogical ambiguities present when different trends, advocated by international research and practice, are followed within a reform context without addressing these issues.

Serbia

Prompted by relatively unsatisfactory TIMSS results for Serbia in 2003 and 2007 regarding achievement of students in grade 8 (below 500 points), TIMSS cognitive domains have been incorporated into national educational standards for the end of primary education in grade 4. These cognitive domains, introduced in the TIMSS 2007 assessment cycle (Mullis et al., 2005), were knowing, applying and reasoning. The incorporation was done in the following way: three achievement levels (basic, intermediate and advanced) in the standards were defined in terms of six cognitive categories (knowledge, comprehension, application, analysis, synthesis and evaluation) based on Bloom and Krathwohl (1984).

These cognitive categories were mostly used in a way that corresponds to the TIMSS cognitive domains. The basic level, involving cognitive categories knowledge and comprehension, corresponded to knowing. The intermediate level (with comprehension and application as cognitive categories applied) corresponded to application, whereas the advanced level (requiring analysis, synthesis and evaluation) corresponded to reasoning. However, TIMSS cognitive domains are not mentioned in official documents describing the development of these standards. Instead, the application of Bloom's taxonomy is mentioned (Pejić et al., 2013).

Standards-based curricular changes (IEQE, 2009) were initially supported by comprehensive assessment-related material comprising a CD with one hundred carefully developed, TIMSS-like tasks that assessed mathematical knowledge in grade 4, and detailed documentation including a computer program to enter and analyse achievement data. These tasks were developed for twenty-five learning outcomes, with four similar tasks per outcome. The material was sent to all schools in Serbia in May 2009 with a recommendation to use it to arrange school assessment by the end of the 2008/2009 school year; according to Stanojević (2010) most schools did so.

Because Bloom's respective cognitive and achievement levels were assigned to each learning outcome, i.e. the task assessing it, an empirical evaluation of the incorporation in question was undertaken. This evaluation confirmed that the incorporation occurred to a considerable extent because the cognitive level assigned to particular tasks (e.g. application) was present at the achievement level assigned to it (e.g. intermediate: comprehension and application) for twenty out of twenty-five learning outcomes mentioned above. Seventeen of these twenty were later used as a foundation of the final set of educational standards for the end of primary education in grade 4, and such a contribution was particularly strong for five learning outcomes in the area of measurement & measures (Kadijevich, 2019).

This final set of educational standards (National Educational Council, 2011) was later operationalised in a 20-task-TIMSS-like test that assessed mathematics learned in grade 3. The test was developed by the Institute for Education Quality and Evaluation in 2014, along with a detailed documentation including a computer program to enter and analyse achievement data. This material was sent to all schools to assist them in carrying out an initial assessment in grade 4 at the beginning of the 2014/2015 school year.

Unquestionably, the use of these assessment materials contributed to teachers' and students' familiarity with TIMSS-like contexts and tasks. This probably contributed to above-average TIMSS results in the Mathematics achievement of grade 4 students in 2011 and 2015, with 516 and 518 points, respectively (Kadijevich, 2019). However, the use of these assessment materials has not been monitored in later years to gather evidence about its opportunities, challenges, or need for improvement. In other words, additional research is needed concerning the application of educational standards for mathematics for the end of primary education in grade 4 and assessments based on them. These standards are still in use today.

What can be learned from the case study from Serbia? One important enterprise has been to develop suitable educational standards and proper assessments based on them. Another equally important one is to assist, monitor, and assess their application in practice and to recognise theoretical and practical issues to improve. This latter enterprise has been wanting.

Conclusion

This chapter examined the role of the two international studies, TIMSS and PISA, as drivers for school mathematics curriculum reforms. These drivers were examined both worldwide and in particular countries, with a special emphasis on ways in which particular components of these studies have been applied in curriculum reforms.

Regarding its general, worldwide influence, TIMSS has primarily contributed to a certain curricular convergence regarding topics to cover and skills to foster, and many national curricula have emphasised the role of problem solving and thinking skills, such as applying mathematics and mathematical reasoning (e.g. Mullis et al., 2016a). PISA influences have primarily dealt with the inclusion of the notion of mathematical literacy, usually expressed in terms of competencies or capabilities (e.g. Stacey et al., 2015; Michel, 2017). However, for both TIMSS and PISA, support for related curricular changes through teacher professional development, has been missing in many countries, as evidenced by Mullis and colleagues (2016c) and Stacey and colleagues (2015).

Deficiencies regarding teacher support for curricular changes are reported by four case studies dealing with particular influences of TIMSS and PISA in Australia, Israel, Mexico and Serbia. Although these studies present diverse influences – from critical curricular notions (Australia, Mexico) to instructional programs involving low and high achieving students (Israel) to educational standards (Serbia) – they highlight that curriculum solutions should be justified, flexible, and progressive for the benefits of their implementers, but also be the subject of continuous monitoring.

Integration into national educational policy processes with various stakeholders involved is needed if countries are to benefit from the influence of TIMSS and PISA on mathematics curriculum, through their assessments or national/regional assessments. The study of Lietz et al. (2016), which calls for such integration, evidences that it is unlikely to happen in economically less developed countries, due to*, inter alia*, lack of a continuing and secure line of funding covering the realisation of various assessment stages, including educational policy change. Having in mind the orientation of international assessments studies in recent years to apply e-assessment, many countries would apply this, especially in the time of the Covid-19 pandemic. In Serbia, for example, to help students prepare for their matriculation exam at the end of grade 8 (the so-called *mala matura*), this exam was nationally simulated online in April 2020 and almost all students participated in this kind of knowledge self-evaluation.[2]

Bearing in mind that TIMSS or PISA components have been embedded in national policies in varying ways and to different extents, further research may focus on various interpretations made and implementations applied (Michel, 2017).

[2] Each of the three tests applied was solved by more than 60,000 students (more than 90% of the whole population). Source: http://www.mpn.gov.rs/analiza-onlajn-testova-za-samoprocenu-znanja-za-zavrsni-ispit-i-postavljanje-testova-i-rezultata-sa-prethodnih-zavrsnih-ispita/

This research should not only compare these interpretations and implementations in different countries, but also examine the limitations of these influences, due to the historic and cultural contexts of respective countries. This research would help to us to understand better the development of mathematics curricula worldwide, as well as to identify how better to support teachers' professional development in implementing such curricula for the benefits of all students.

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