International Commission on Mathematical Instruction

ICMI Study 24

SCHOOL MATHEMATICS CURRICULUM REFORMS: CHALLENGES, CHANGES AND OPPORTUNITIES

DISCUSSION DOCUMENT

Prepared by the International Program Committee

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1. INTRODUCTION AND BACKGROUND

School mathematical reforms have taken place in many countries around the world in the recent past. Although contexts vary significantly much could be learnt from deeper and more substantial reflections and research about different aspects of these reforms.

Reforms have been large-scale involving an education system as a whole, at a national, state, district or regional level in which mathematical curricula, standards or frameworks have been developed and implemented. Changes have taken place at all levels of mathematics in the school educational system from pre-primary through senior secondary.

School mathematics reforms are often conducted with changes in all different aspects of the curriculum: mathematics content, pedagogy, teaching and learning resources (e.g. texts and technologies), and assessment and examinations.

It is possible to observe different influences on school mathematics curriculum reforms over time. During the mid-twentieth century school mathematics curriculum reforms were shaped by developments within the discipline of mathematics and by the ideas of some mathematicians. This is captured in an address by Dieudonné, one of the proponents of what was then termed the "New-Math" in 1959:

> "In the last fifty years, mathematicians have been led to introduce not only new concepts but a new language, a language which grew empirically from the needs of mathematical research and whose ability to express mathematical statements concisely and precisely has repeatedly been tested and has won universal approval.
>
> But until now the introduction of this terminology has been steadfastly resisted by secondary schools, which desperately cling to an obsolete and inadequate language. And so when a student enters the university, he will most probably never have heard such common mathematical words as set, mapping, group, vector space etc."
>
> (Cited in Howson et al., 1981, p. 102)

The New-Math reform, took place in a particular historical context of the "cold war". It became a mathematical movement that spread to many countries around the world with different influences on national curricula and practical implementations in schools. The character of this reform and its challenges was a departing point for many developments and discussions in the teaching of mathematics. Since then, with the lessons from the New-Math reform movements, the field of mathematics education has progressed

immensely.

Another major influence on school mathematics curriculum reforms in the second half of the twentieth century has been from outside mathematics, that is, developments in other disciplines, most notably, psychology. Studies and theories in behaviourism, the rise and development of cognitive science and constructivism, to name a few, have especially impacted pedagogical approaches advocated in mathematics curriculum reforms. Other trends in mathematics curriculum reforms included problem solving, and back to basics, (among others).

More recent influences on mathematics curriculum reforms, in this twenty first century, have come from other areas, such as large international studies, especially those focusing on student achievements. These studies have enabled comparisons of mathematics curricula (such as intended and attained curricula) across many countries and generated particular conceptions (such as mathematics literacy), which have found their way into mathematics curriculum reforms. Nowadays international comparative studies like the Trends in International Mathematics and Science Study (TIMSS) (Mullis et al, 2016) and the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) (OECD, 2016), which attract a great deal of public attention and media focusing on student and teacher performance in mathematics education (and to which politicians and policy makers are especially responsive), are impacting and shaping school mathematics curriculum reforms as countries or regions both compete and share curriculum policies, materials and approaches. These studies have raised the stakes significantly, and arguably, entrenched a focus on student performance and better test scores as opposed to better student learning within mathematics curriculum reforms. There are a diversity of studies and findings from international experience and research that can and does influence the nature of curriculum changes, and the possibilities of educational reform and its implementation: - curricular design results; a revised role for components in the teaching of mathematics (e.g. mathematics content, pedagogy, and assessment); the role of technology; and new cognitive, sociocultural and sociopolitical perspectives.

In recent years the internationalisation and globalisation of the economy, universality of technological development and related needs for new skills and knowledge play the role of strong motivations for curriculum reforms that have brought calls for unified standards for mathematics in school. In the international debate, many scholars, teachers

and policy makers now speak of the "*21st century competencies*" and consider important items like: "critical and inventive thinking; communication, collaboration and information skills; and civic literacy, global awareness and cross-cultural skills"[i]. In many countries, the so called "21st century competencies framework"[ii] is being worked on, in order to guide the development of the national curriculum and to design school-based programmes to nurture these competencies.

In relation to this, new mathematics curriculum discourses have emerged and taken hold. Notions of mathematical "competencies" and that of mathematical "literacy" are important examples that have been raised, from different perspectives around the world (Niss, 2015). In particular, from the approach of OECD's PISA, several notions (and their underpinning theoretical framework) have become very influential in many countries in the changes being made in local curricula and standards; for example, in Denmark, Germany, Japan, South Korea, Costa Rica, Spain, Norway, Mexico, Sweden. PISA stresses the role of mathematical literacy as a central goal in school mathematics education, because it improves the life chances of most students, and justifies why mathematics is essential to describe, explain and predict the world. According to the PISA 2015 Mathematics Framework,

> "Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens."
>
> (OECD, 2016, p. 65)

However, the word literacy itself is ambiguous with multiple meanings, and trying to translate it into different languages and cultures is a difficult, if not sometimes impossible task. In the literature, one finds different names and definitions; and many changes over the years showing the notion of literacy to be

> "a socially and culturally embedded practice, and …[its] conceptions … vary(ing) with respect to the culture and values of the stakeholders who promote it"
>
> (Niss & Jablonka, 2014, p.395).

The differences in approach are directly linked with the goals that are pursued in mathematics education in individual countries. Its inclusion in curriculum reforms

identifies new demands about what citizens are obliged to know (or not allowed to ignore). Hence a careful analysis of this notion is required in order to focus its rationale in a curriculum.

Moreover, international studies that examine the successes and failures in achieving the promised aims from different reforms, across these countries, equally need to be undertaken. For instance, the aftermath of the New-Math reform alludes to the importance of reflecting on the requirements for a new curriculum, suitable to escape the causes of the complete, or partial rejection of this reform in so many countries.

The challenges of this particular reform and others that followed opens a discussion about different aspects of curriculum reforms, which go beyond content, such as:

- The existence of different epistemological and cultural positions concerning mathematics and its relevance in different societies;
- The distance of the proposed reform from the mathematical, educational and material conditions and possibilities in different countries, including teacher quality, their preparation, knowledge, beliefs and expectations;
- The relationships with the social, cultural and personal contributions brought by the students in the classroom, so relevant to avoid students' alienation from their social and cultural environment and to allow students to engage in learning in a productive way; and
- The influence of political and institutional scenarios within educational systems, that can promote, discourage or weaken curricular reforms.

A consequence of these reflections is that the communities of researchers, teachers and policy-makers need to become more aware that considerations of curriculum reforms from various perspectives and constructs (mathematical literacy or competencies, for instance) raises many issues, from a scientific, political and cultural point of view.

This ICMI study topic invokes not only questions about changes in curriculum design but – with force - questions about the implementation of these changes across an educational system. A curriculum reform will be influential or have impact in so far as it can be implemented and sustained. What has functioned (or not) at the time of implementing a curricular change? What are the limitations? How have resources (e.g. textbooks and technology) influenced the reforms and their enactment? How must large scale teacher preparation be conducted to achieve the reform goals? How do diverse social, economic, cultural and national contexts condition the nature and extent of

curricular reforms; especially teacher expectation, attitudes and beliefs; and the social and cultural background of students? How are assessments of students' learning influential in curriculum reforms? An ICMI Study offers an opportunity to provide a synthesis and meta-analysis of different aspects of school mathematics reforms historically, geographically and globally.

There are many studies conducted in different parts of the world about these issues of mathematics curriculum reforms and their implementation with findings that can be systematized, compared and studied. The way curricula are elaborated, proposed, changed, and reorganized is, however, still a rather under-explored area in mathematics education. This ICMI study can allow a more informed and comprehensive analysis of the roles of different actors and of the many aspects influencing and shaping mathematics curriculum reforms that are or have taken place; and of the possibilities and means to tackle a curricular reform in the current scenario we live in and unfolding future developments.

2. AIMS AND RATIONALE

Nowadays, a central issue for many countries and education systems, and for many social and educational actors, is to carefully reconsider and revise the nature of school mathematics; to come to a more precise meaning of curriculum reform; and to scrutinise the diverse strategies for its implementation. There is a need to identify common ground, and to point out findings and good practices to enable effective, efficient and successful school mathematics reforms.

A study that sheds light on what "works" and what does not in school mathematics curriculum reforms and their implementation across diverse contexts would be of great value and use not only for policy makers, administrators, and researchers, to learn from each other's countries and regions, but also to practitioners and to educational communities as a whole. It is a key imperative for many countries to enhance the competencies of students who will become key players in changing societies, given the internationalisation and globalization of the economy, and rapid advancement of communication and other technologies. What is currently taught and learnt as school mathematics is challenged in this evolving context.

It is as crucial an issue for developing countries, as it is for developed ones, given by the global changes taking place in societies, as they confront different challenges of

growing inequality, unemployment, poverty, mass migration, environmental disasters, and conflicts (to name but a few), and within which school mathematics reforms must take place. However, the processes of curriculum reform may differ in developed versus developing countries due to different protocols followed, different intentions and agendas as well as policy and political rhythms. Other comparative fault lines are, for example, East-West differences in mathematics curricula and reforms which have gained much interest, largely from the results of international studies.

A further rationale for this study is to stimulate further research and publications that explore mathematics curriculum reforms especially at a policy level and across multiple and diverse contexts. Some recent volumes such as by Li and Lappan (2014) point to the growing need for further work in this area and its potential for more research- and evidence-based policy generation as well as implementation models and frameworks.

An ICMI Study offers a unique opportunity to examine past and present mathematics curriculum reforms in different parts of the world, from a macro perspective and meta level and to investigate larger questions of who or what sectors of society drive and most influence curriculum reforms, what reforms precisely are taking place, how are these being implemented, and if they are deemed successful (or not), what count as success. Hence, this study has the potential to build understanding of the implications – current and future – of these larger questions for school mathematics, for different aspects of teaching and learning mathematics, and for its role in the broader society.

Clearly a wide range of specific questions may be raised with respect to this broad topic of school mathematics curriculum reforms. However, these may be engaged by clustering them within a selection of themes as set out in the next section.

3. THEMES AND QUESTIONS

The overarching question of this ICMI Study is to explore what school mathematics curriculum reforms have been or are taking place, especially at a meta, macro or system level; and to learn about the many different aspects of mathematics curriculum reforms from past experiences, to specify the current status and issues in reforms world-wide, and to identify possible directions for the future of school mathematics.

The following five themes are selected for the study to address the research questions.

A. Learning from the past: driving forces and barriers shaping mathematics curriculum reforms

B. Analysing school mathematics curriculum reforms for coherence and relevance
C. Implementation of reformed mathematics curricula within and across different contexts and traditions
D. Globalisation and internationalisation, and their impacts on mathematics curriculum reforms
E. Agents and processes of curriculum design, development, and reforms in school mathematics

Each of these selected themes is aligned with a group of specific questions to be addressed in the study.

In the following discussion, we need to note that key distinctions are needed in conceptualisations of curriculum in a study on curriculum reforms (e.g. Mullis & Martin, 2015).

- Intended curriculum, implemented curriculum, and attained curriculum
- Curriculum at the system level, classroom level, and student level
- Curriculum as a product and curriculum as a process

We focus on an intended curriculum and insofar as it is concerned with and takes account of the implemented and attained curriculum at the level of the classroom and student respectively, and on the level of educational systems, and on the dynamics of curriculum as a process, at the phase of educational reforms and in the context of societal needs expected of school education in different countries.

For each of the themes below, different curriculum components may be analyzed such as content, pedagogy, textbooks, technology, assessment, initial and continuing teacher professional development, curriculum development and design processes, and the role of agents. Contributions are invited to the separate themes and will be distinguished by the theme's specific foci and questions.

A. Learning from the past: driving forces and barriers shaping mathematics curriculum reforms

School mathematics curriculum reforms are contested spaces with many different vested interests because of the multiple goals and intentions they are expected to serve. Therefore, in any curriculum reform, there are both driving forces and barriers in shaping mathematics curricula. This first theme sets a general background and the context, and invites studies of school mathematics curriculum reforms in the past decades.

A1. What aspects of school mathematics curriculum reform carried out in the past decades are considered to be the most important (for example, in content, pedagogy, and in the underpinning theoretical approaches)? What potentially crucial aspects of mathematical curricula have not been considered, and even less, touched upon?

A2. Which goals and values in school mathematics curriculum reforms, carried in the past decades, have been the most important (for example, in the selection and organisation of mathematics contents, or process aspects of mathematical activities)?

A3. How have the questions of content become linked to the notions of mathematical competencies, capabilities, and literacy; and how have these evolved to become a driving force in the curriculum development and reform initiatives?

A4. What has been the role and function of curriculum resources, materials, and technology, including digital curricula and textbooks in curriculum reforms and their implementation as driving forces or barriers?

B. Analysing school mathematics curriculum reforms for coherence and relevance

The role, content, and importance of mathematics as a school subject are examined in each educational system from time to time. All mathematics curricula set out the goals

expected to be achieved in learning through the teaching of mathematics; and embed particular values, which may be explicit or implicit. Recent emphases on STEM (Science, Technology, Engineering, and Mathematics) education in many countries raises both the question of the place of mathematics among these subjects, and the discussion of introducing an integrated or interdisciplinary subject. Questions about the study of school mathematics curriculum reforms are raised in this context for their coherence and relevance.

B1. What is the extent of coherence within and among different aspects of reformed curricula such as values, goals, content, pedagogy, assessment, and resources? How are curriculum ideas organised and sequenced for internal coherence in a curriculum reform? What are the effects of a lack of coherence? For example, regarding relations between high-stakes examinations and curriculum reforms.

B2. How are mathematics content and pedagogical approaches in reforms determined for different groups of students (for e.g. in different curriculum levels or tracks) and by whom? How do curriculum reforms establish new structures in content, stakeholders (e.g. students and teachers), and school organisations; and what are their effects?

B3. What interrelation between mathematics and other disciplines, or movement toward integrated or interdisciplinary curricula, can be observed in mathematics curriculum reforms, given the current emphases on STEM education? What is the relationship between school mathematics and mathematics as a discipline in school mathematics curriculum reforms?

B4. What curriculum materials development and technology are or have been engaged, and what are their roles, goals, and underlying values in school mathematics curriculum reforms?

B5. What theories and methodologies are appropriate for studying phenomena related to mathematics curriculum reforms?

C. Implementation of reformed mathematics curricula within and across different contexts and traditions

The cultural, social, economic and political contexts and positions for the implementation of the school mathematics curriculum are important considerations. The processes of implementing new or reformed curricula may differ according to the cultural and historical contexts and traditions due to different protocols followed and the processes of political decision making.

C1. What processes, models, or best/common practices can be identified from the experiences in the implementation of new or reformed school mathematics curricula?

C2. What are examples of successful or unsuccessful reforms and what are the reasons for their success or failure? What criteria are used for assessing curriculum reforms and their degree of success or failure?

C3. How is the implementation of new or reformed curricula monitored, evaluated, and acted upon? What are models or mechanisms of continuous improvement in school mathematics curricula? How does the existence of such a mechanism affect the frequency, (dis)continuity, and perceived challenges and successes of curriculum reforms?

C4. What models or processes for professional teacher preparation and continuous development have been carried out in different countries in the implementation of new or reformed curricula; and what are their influences, effectiveness, successes or failures?

C5. What are the types of resources and what are their roles (e.g. textbooks, materials, technology) in the implementation of reformed curricula?

D. Globalisation and internationalisation, and their impacts on mathematics curriculum reforms

There are a number of factors that advance globalisation and internationalisation through rapid changes in the nature of communication and availability of information. This internationalisation and globalisation of life in the twenty first century seem to affect mathematics curriculum reforms. These influences appear to increasingly lead toward a "convergence" in school mathematics curriculum reforms. Commonalities and diversity may be observed through comparative studies.

D1. How have results of international experience and research in the teaching and learning of mathematics influenced curricula changes? To what extent can local curriculum reforms be examined against an emergent "international" mathematics curriculum?

D2. How have particular international studies become drivers for school mathematics curriculum reforms? What new discourses with dominant theoretical and conceptual underpinning have emerged; and how have these been taken up in curriculum reforms in different contexts? For example, how have the OECD's PISA notions of mathematical literacy and mathematical competencies been interpreted and expressed in curriculum reforms?

D3. How are mathematics curriculum reforms varied (or similar) in different social, cultural, economic and political contexts such as developing versus developed countries or East versus West? How do selected curriculum components such as content, pedagogy, materials technology and teacher preparation vary from one reform, tradition, country or context to another?

D4. How can comparative or meta analyses of curriculum reform processes and implementations shed light on what works or does not work in mathematics curriculum reforms in contemporary societies?

E. Agents and processes of curriculum design, development, and reforms in school mathematics

Curriculum reform processes are as much an educational matter as they are political; and nowadays involve a broad range of stakeholders with vested interests. Educational, social and political actors influence and shape curriculum reforms – from business, industry, media, teacher unions, and parents on the one hand; to those with different expertise such as curriculum policy makers, educators, mathematicians, researchers, on the other hand.

E1. What are the processes, and how are they deployed, in the development of and during a mathematics curriculum reform? What agents lead or dominate and what is their influence on the aspects of curriculum reforms?

E2. What different roles do mathematics teachers, teacher educators, (education) researchers and mathematicians play in curriculum reforms? What kind of influences do these role players have in mathematics curriculum reforms?

E3. How (if at all) is public engagement with the mathematics curriculum reforms organised and managed; and who takes or is given this responsibility? What is the role and influence of different media in curriculum reforms?

E4. To what extent does or could research inform or influence curriculum design and development processes in reforms?

4. THE STUDY CONFERENCE

ICMI Study 24 on school mathematics curriculum reforms is planned to provide a platform for teachers, teacher educators, researchers and policy makers around the world to share research, practices, projects and analyses. Although these reports will form part of the program, substantial time will also be allocated for collective work on significant problems in the topic, that will eventually form parts of a study volume. As in every ICMI Study, the ICMI Study 24 is built around an international Study Conference and directed towards the preparation of a published volume.

The Study Conference will be organized around working groups on the themes. These groups will meet in parallel during the conference. It is the work of these groups that is captured as chapters in the ICMI Study Volume.

Papers are invited in each theme to address the different questions. We encourage papers that are analytical rather than only descriptive. It is expected that interconnections between themes will emerge and warrant attention therefore, papers may be re-allocated if necessary.

4.1. Location and dates

The Study Conference will take place in the Tsukuba International Congress Center, Tsukuba, Japan and will be hosted by University of Tsukuba. The conference will take place from 26 to 30 November, 2018, with an opening reception on the evening of Sunday, 25 November, 2018.

4.2. Participation

As is the usual practice for ICMI studies, participation in the Study Conference will be by invitation only for the main/corresponding authors of the submitted contributions, which are accepted. Proposed papers will be reviewed and a selection will be made according to the quality of the work, the potential to contribute to the advancement of the Study, with explicit links to the themes contained in this Discussion Document and the need to ensure diversity among the perspectives and representation. The number of invited participants will be limited to approximately 100 delegates.

Unfortunately, an invitation to participate in the conference does not imply financial support from the organizers, and participants should finance their own attendance at the conference. Funds are being sought to provide partial support to enable participants from non-affluent countries to attend the conference, but it is unlikely that more than a few such grants will be available.

4.3. ICMI Study 24 Products

4.3.1 The **first product** of ICMI Study 24 is an electronic volume of conference proceedings, to be made available first on the conference website and later in the ICMI website. It will contain all the accepted papers as reviewed papers in a conference proceeding with an ISBN number, which can be cited as a refereed publication, but are published online only.

4.3.2 The **second product** is the ICMI Study 24 volume. The volume will include the outcomes of the discussions at the conference on the themes in this Discussion Document, informed by the papers. It must be appreciated that there will be no guarantee that any of the papers accepted in the study conference proceedings will appear in the book.

The ICMI Study will be an edited volume published by Springer as part of the New ICMI Study Series. The editing process and content will be the subject of discussion among the International Programme Committee (IPC). It is expected that the organization of the volume will follow the organization and themes set out in this Discussion Document, although some changes might be introduced to incorporate the discussions raised during the conference. Hence the chapters in the volume collectively and consensually integrate the outcomes from the parallel working groups of the ICMI Study Conference.

A report on the study and its outcomes, if not the completed ICMI Study 24 volume, will be presented at the 14th International Congress on Mathematical Education (ICME 14), to be held in Shanghai, China, from 12 to 19 July, 2020.

5. CALL FOR CONTRIBUTIONS

The IPC for ICMI Study 24 invites submissions of contributions of several kinds which include: research papers related to school mathematics curriculum reform issues; theoretical, cultural, historical, and epistemological essays (with deep connection to curriculum reforms); discussion and position papers analysing curriculum policy and practice issues; synthesis and meta-analysis reports on empirical studies; reviews of curriculum reform efforts, especially at macro levels; and papers on comparative studies in curriculum reform initiatives.

Authors must select one theme from among the five described in this Discussion Document to which their paper must be submitted. Authors are expected to consider the questions listed below each theme in making their decision to submit papers.

To ensure a rich and varied discussion, participation from countries with different economic capacity, and different social, political and cultural heritage and practices is encouraged.

The IPC encourages people who are not familiar with such conferences to submit early and request assistance for finalizing their contribution (by 28 February, 2018 - this

assistance concerns the choice of the paper topic, theme or structure, not the editing of English language). In this way, the IPC supports a tradition of helping newcomers to the international mathematics education community[1].

An invitation to the conference does not imply that a formal presentation of the submitted contribution will be made during the conference or that the paper will appear in the study volume published after the conference.

5.1 Submission

A template for the submission of papers is available on the ICMI Study 24 website (see below). Papers prepared in English (the language of the Study Conference) according to the template and a maximum of 8 pages must be submitted by the deadlines set out below.

5.2. Deadlines

30 April, 2018: Submissions must be made online no later than 30 April, 2018, but earlier if possible.

30 June, 2018: Papers will be reviewed, decisions made about invitations to the conference, and notification of these decisions will be sent to the corresponding/main author by the end of June.

Information about registration, visa application, costs, and details of accommodation may be found on the ICMI Study 24 website:

http://www.human.tsukuba.ac.jp/~icmi24/

6. MEMBERS OF THE INTERNATIONAL PROGRAM COMMITTEE (IPC)

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[1]Those who need assistance for finalizing their contribution must submit a tentative copy of their paper requesting assistance no later than 28 February, 2018. Their submissions will be examined immediately. An IPC member may be assigned to help with the final preparation of the paper. Then the final paper will undergo the standard review process.

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7. REFERENCES

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[i] See for example the Singapore Ministry of Education website accessed 6 December 2017: https://www.moe.gov.sg/education/education-system/21st-century-competencies

[ii] See for example *Towards Defining 21st Century Competencies for Ontario, Canada* accessed 6 December 2017: http://www.edugains.ca/resources21CL/About21stCentury/21CL_21stCenturyCompetencies.pdf