Chapter 24
Conclusion: Future Visions of the Impact of Internationalisation and Globalisation on School Mathematics Curriculum

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The ICMI Study 24 Discussion Document and its research questions for theme D focused our attention on drivers that have influenced changes in the school mathematics curriculum. These were addressed in the previous texts of the theme *Globalisation and internationalisation, and their impacts on mathematics curriculum reforms*. In the Introduction, we identified "international drivers of the curriculum". In Chap. 21, we examined the evolving definitions of numeracy and mathematical literacy. In Chap. 22 we surveyed the role of international assessments, namely PISA and TIMSS, in shaping curriculum reforms internationally and locally; and in Chap. 23, we discuss the inclusion of computational (algorithmic) thinking in mathematics curriculum reforms.

Internationalisation and globalisation are now irreversible phenomena. However, we do not believe that these necessarily lead to a uniform or common international curriculum in mathematics. The *fourth industrial revolution* will certainly allow for immediate sharing of resources for teachers, students, and school systems. But it will also allow for greater variety and local adaptations as more stakeholders and participants are involved in the process of curriculum improvement and curriculum commentary. A wider range of resources will include curriculum materials, resources to support teaching, student activities, and assessment.

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Y. Shimizu, R. Vithal (eds.), *Mathematics Curriculum Reforms Around the World*, New ICMI Study Series, https://doi.org/10.1007/978-3-031-13548-4_24

We consider it unlikely that the future will see a return to the *New Math* model of past decades where the range of participants was limited and the boundaries for participation were tightly and somewhat hierarchically defined. A top-down model of promotion and dissemination made sense in a pre-digital age of Internationalisation. Future national and regional priorities should be better informed. In our opinion, globalisation could foster greater innovation and experimentation rather than uniformity.

Internationalisation and globalisation are also intrinsically connected to competition and differentiation between countries. We can expect continued reliance on international assessments by which countries attempt to measure the degree of improvement of their local curriculum and their international rankings. Local cultural factors and historical traditions will not disappear. We are concerned that there will be an ever-widening gap between well-resourced countries who can afford to experiment and choose from the range of available resources and those countries with more limited resources and fewer options.

Influence of TIMSS and PISA

We have seen and compared the impact of TIMSS and PISA in economically and geographically diverse countries, being concerned not simply with reform of the intended curriculum but supporting teacher professional development offered. In some places, our narrative pointed to variations in the curricular solutions applied, as well as to what worked and what did not work in some of these solutions.

Although particular components of TIMSS and PISA studies (e.g. knowledge to cover and skills to foster, mathematical literacy to develop) have influenced curriculum reforms in many countries worldwide, we saw that appropriate policy support for such curricular changes has often been missing or limited. Curriculum solutions should not only be justified, flexible and progressive, but also need continuous monitoring in order to benefit mathematics education.

For TIMSS and PISA, we anticipate several changes: the inclusion of a greater range of abilities in TIMSS and PISA (e.g. computational thinking), and the transformation of traditional paper-and-pencil assessments into e-assessments administered in digital format using some novel assessment tasks. Both changes will influence future curriculum reforms worldwide. We believe that *PISA for development* (OECD, 2016) will show how international assessments can be better tailored to meet the needs of low- and middle-income countries while supporting evidence-based policy making and offering globally applicable tools in monitoring progress towards commonly agreed education sustainable development goals.

Evolving Understandings About Numeracy and Mathematical Literacy

We analysed the emergence of understandings about numeracy and mathematical literacy and compared their relationship to curriculum reform processes in selected countries. Future research could address questions in three areas: (1) how the meanings numeracy and mathematical literacy might continue to evolve; (2) how numeracy and mathematical literacy can be represented in the school curriculum; (3) how to support teachers in developing students' numeracy/mathematical literacy.

We have seen how the PISA definition of mathematical literacy has changed in subtle ways over time in response to "new challenges and opportunities in all areas of life" (OECD, 2018, p. 3). For example, the PISA 2021 mathematical literacy framework retains its emphasis on problem solving, but gives increased emphasis to mathematical reasoning and, for the first time, includes some aspects of computational thinking. These changes present opportunities to investigate their impact on curriculum reform across countries. We also saw different approaches to incorporating numeracy and mathematical literacy into the school curriculum: as a separate subject, a twenty-first-century skill to be developed in all subjects, or a new emphasis on applying mathematics in real-life contexts within the regular mathematics curriculum. Future research needs to investigate the benefits and disadvantages of each of these, and other, curriculum approaches. Finally, we reiterate that teachers are responsible for implementing reforms that integrate numeracy and mathematical literacy into the school curriculum.

For *computational (algorithmic) thinking*, our future vision embraces five key elements:

Realise the importance of CT/AT

Computational thinking is now omnipresent in the sciences, in data analytics and forecasting. Its ever-expanding global applications are defining features of the twenty-first century. We have already seen that PISA 2021 includes computational thinking as a component of mathematical literacy, demonstrating that computational thinking is important for all students not only for those who are interested in computer science or mathematics.

Use CT/AT related resources

We saw that many countries are already launched on this pathway, and while different descriptors may be used, a common focus is on *thinking*. Computational thinking is more than learning to code. We identified the need for research to elucidate the connections between CT/AT and mathematical reasoning and problem solving. Some activities at all stages of schooling will need to be *computerless* or *unplugged*. We identified resources provided by educational agencies, private foundations, laboratories, and universities to support computational thinking. Internationally available resources will continue to provide different platforms for innovation and experimentation.

Relate CT/AT and mathematical thinking

Computational methods and the use of computer-based algorithms are now established features of undergraduate programs at universities, and in the world of work. Establishing curriculum connections between Computational (Algorithmic) thinking and mathematical thinking is urgently needed for primary and secondary schools. Educational policies are needed to connect curriculum content, teaching approaches, modes of delivery, and assessment – and on the direction and rate of change.

Embedding CT/AT into the mathematics curriculum

This will include at least five dimensions: data *practices*, modelling and simulation *practices*, computational problem-solving *practices*, algorithm design *practices*, and systems thinking *practices*. We expect fluidity among educational policy makers on the degree to which these *practices* are incorporated into the school mathematics curriculum or into other curriculum areas. These practices are all multifaceted and require research on students' computational thinking abilities in parallel with their mathematical and other school studies. International studies are needed to explore these dimensions.

Develop CT/AT related educational policies

As a component of mathematical literacy, computational thinking will have a firm place in the curriculum for compulsory education. A key policy decision is where to split the focus between compulsory education and the later years of schooling where greater opportunities for choice and specialisation can be provided. We recognise that implementing CT/AT in the curriculum will be challenging for teachers with no recent university studies in computational mathematics, computer science, or related areas. A key policy decision, therefore, will be determining the rate of change, and providing for teacher professional learning. In-school models where teachers of mathematics work in partnership with computer science colleagues are likely to improve teacher capacity. The pressure to keep abreast of these changes will weigh heavily on countries and regions that are not resource rich. International leadership including that of ICMI will be essential to prevent disparities widening even more.

Finally, what have we learned from the issues investigated in the theme *Globalisation and internationalisation, and their impacts on mathematics curriculum reforms*? Four *general recommendations* are important for future curriculum reform:

- creating opportunities for collaborative work with different stakeholders (teachers, researchers, curriculum designers, industry partners) to understand complex relations among which components to be included; what national policies to revise; and what reforms to undertake;
- evaluating the opportunities and challenges when adapting components of international studies in national curriculum policies;
- developing and testing practical models of teacher preparation that align with the responsibilities outlined in the official curriculum;
- building teacher capacity to understand these components and integrate them in the classroom for the benefits of all students (extrapolated from Webb et al., 2017).

Acknowledgement The research done by D.M.K. was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (contract no. 451-03-68/2022-14/200018).

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