The seventeenth ICMI study: Technology revisited.

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The ICMI Executive Committee (EC) decided in July 2002 to launch a new ICMI Study, ICMI 17. In the letter that invited us to chair this study, the EC announced that the theme would be "Technology revisited" because the very first ICMI Study, held in Strasbourg in 1985, was on the influence of computers and informatics on mathematics and its teaching. The letter also made clear that the EC did not see ICMI 17 as focusing on the development of a prospective view nor as appropriate for developers to simply present their latest productions. Rather, the EC asked us to look at what had been achieved over the last decades and to attempt to assess the impact of technology on the teaching and learning of mathematics. Later, when discussing the composition of the International Program Committee (IPC), we decided explicitly to consider the situation of developing countries and to ensure our work included an exploration of how far technology might be used for the benefit of mathematics education in these countries, rather than yet another source of inequality.

At the time we submit this paper, the Study Conference for ICMI 17 has taken place (Dec 2006) but it is still one year to the publication of the Study book. This paper therefore presents us with an opportunity to take stock of the work carried out during the five busy years since the original invitation. We recall the main points of our Discussion Document, specify the rationale and the goals of ICMI 17, present an overview of the Study Conference and finally, outline the expected structure of the Study book.

1. Why ICMI Study 17?

The first ICMI Study

The first ICMI study, undertaken in 1985, discussed the use of computers in mathematics education and was one of the first attempts to develop a critical view of the role and influence on mathematics education on what was termed 'informatics'. ICMI 1 had a substantial impact, with the study book first published by Cambridge University Press[1], and reissued in 1992 by

UNESCO[2]. In this latter volume, a major mismatch in timescale was noted between the fast pace of change of technology, the slower changes in research in mathematics and the still slower changes in mathematics education and in the curricula, particularly in relation to integrating technology into teaching and learning.

Some 20 years later, ICMI 17 again set out to provide critical reflection on this area. Consideration of the first ICMI study provided an interesting starting point: even a cursory glance revealed that the authors worked in a rather restricted set of countries (Europe and North America), and the focus of the papers was almost exclusively on using computers to engage with models of rather advanced mathematical ideas. Many authors pointed to the potential of using 'symbolic manipulators' in courses of calculus or linear algebra in order to allow students to focus on conceptual rather than procedural or technical issues. It is worthwhile noting that despite identifying such potential, there was little evidence of significant impact on the mathematics curriculum of secondary schools and universities (primary-level mathematics not being considered): reasons put forward included mathematicians' lack of experience in using the systems and an absence of strategic approaches to change.

Digital technologies: Further developments and questions of impact

The Discussion Document for ICMI 17 started by noting that since 1992, there had been substantial developments in digital technologies, in terms of hardware and software: for instance, in calculator technology and the use of the Internet, computers of all types, and digital technology such as mobile phones and digital cameras used widely in society at large. These developments together with associated software have potential implications for mathematics teaching and learning at all phases of education, and indeed outside the formal contexts of school. Digital technologies have become ever more ubiquitous influencing most, if not all, education systems. In many countries, it is hard to conceive of a world without high-speed interactivity and connectivity. ICMI 17 sought to take stock of these developments and assess their impact in the broadest terms.

Developments in digital technologies have spawned a broad range of studies, encompassing many perspectives, theoretical frameworks and methodologies, with some focusing on the impact of specific software, others looking more broadly at the interactions between teachers, students and technologies. This corpus of work can - potentially at least - influence

mathematics education more generally: as Hoyles and Noss (2003) claimed: "there are major research issues for mathematics education that are shaping and being shaped by the issues confronting 'technologists'"[3] How far these issues have been addressed and their potential realised for the improvement of mathematics teaching, learning and the curriculum, was a subject of debate in ICMI 17.

Key challenges for ICMI 17 as set out in its Discussion Document

ICMI 17 set out to identify and analyse some of the challenges in mathematics teaching and learning, practically and theoretically, in the light of the use of digital technologies. Most digital technologies do not make explicit how they work or how they can be used in mathematics education, which means there are challenges in taking account of their design. A focus of the work was therefore to try to unpick the reciprocal influences of tools, epistemology and teaching/learning communities.

In ICMI 17, we not only recognised the diversity in the software and hardware now available for use in mathematics education, but also considered the influence of diverse curricula organisations, from highly centralised to locally autonomous, and of the availability of resources in different countries – whether it involved access to handheld devices, computers or to the web. ICMI 17 also took account of cultural diversity and how issues of culture alongside those related to teacher beliefs and practice, all shape the way digital technologies are used and their impact on mathematics and its teaching and learning.

2. Aims of the Study

In a varied and evolving context, ICMI 17 sought a balance between two, potentially contradicting, aims:

- to reflect on *actual* uses of technology in mathematics education, avoiding mere speculation on hypothetical prospects,
- to address the range of hardware and software with a *potential* to impact upon or contribute to mathematics teaching and learning.

While we noted the first Study was largely focused on modelling mathematics, more recently work has focussed much more generally on the multitude of ways technology can shape teaching and learning mathematics, while reciprocally being shaped by its use. For example,

studies have looked at the complex process of instrumental genesis, the role of the teacher and the connection of tool use and traditional techniques[4]. New robust paradigms for thinking about tool use in the context of mathematics education are beginning to emerge and ICMI 17 aimed to take further steps forward in this direction.

3. The Study Conference

The Study Conference took place in Hanoi, Vietnam from 3-8 December 2006, and was hosted by the Hanoi Institute of Technology. Choosing to have this ICMI Study in Vietnam was for the IPC and the ICMI EC a way of ensuring that the voices of countries often poorly represented at ICMI events would be present and that their contribution would help the work to be sensitive to the question of cultural diversity.

Participants

About 100 invited delegates attended the Study Conference[1] distributed as follows: Africa 3; Asia 9; Australia, New Zealand 11; Central and South America 8 ; Europe and Russia 52; Middle Orient 9; USA and Canada 22.

Plenaries

Two plenary keynotes were scheduled, at the beginning and the end of the conference. For the first, we wanted an address that set the scene for our meeting, that exhibited deep insight and clear vision, and would present issues (some maybe controversial) for the meeting to debate. We were delighted that Seymour Papert accepted our invitation. He delivered the first talk of the conference, titled: *30 years of digital Technologies in mathematics education and the future*. As part of the presentation, Seymour showed us the $100 Laptop to illustrate his argument that easy access to computers could lead the way to a radically new approach to mathematics education especially for developing countries.

His accident the next day was a terrible shock for all the conference and cast a dark shadow over the rest of the meeting – and beyond. Nonetheless, we tried to sustain his presence by following up his ideas in our subsequent work: specifically that 10% of all our efforts should be to rethink the nature of mathematical knowledge in the computer era.

[1] ICMI 17 was able to award some support for attendance thanks to the sponsorship raised.

Michele Artigue, now President of ICMI, gave the concluding keynote: *The future of teaching and learning mathematics with digital technologies.* Drawing on her experience as a researcher in the field, Michele recalled the evolution of the technological landscape and of research since the first ICMI study, pointing particularly to equity issues that were hardly mentioned twenty years ago and to the wealth of theoretical constructs that have now emerged in order to address technological issues in mathematics education. She structured her lecture around five perspectives: theories, the teacher, curricula, design, and regional diversity across the world.

Other plenaries were organised in panels. Consistent with the Study's focus on cultural diversity, one panel was based on presentations from selected continents to showcase the *diversity of technology implementations* especially in the less affluent regions of the world. The themes of the other two panels were chosen to reflect two critical concerns in technological implementation, namely *connectivity* and *design*. With the development of networks and the web, connectivity has the potential to have a strong impact on mathematics education, although research on this topic is still in its infancy. The *connectivity panel* set out to show the potential of the web both in the individual presentations of the panellists in Hanoi and also through a videoconference link with researchers in Lyon, France, a use of connectivity that is now common in developed countries, but not so familiar in other regions. The *design panel* started from the assumption that design was crucial to effective educational use of technology. Particularly in the case of widely used educational tools, decisions taken by a small number of designers shape the way educators have to think of teaching and learning with the technology. The panel showed with specific examples of well-known software widely used in mathematics classrooms across the world, how design decisions were made, how they were connected with visions of teaching and learning, and how they could give rise to change in the classroom.

Working groups for invited delegates

Seven themes had been distinguished in the Discussion Document of the Study: (1) Mathematics and mathematical practices, (2) Learning and assessing mathematics with and through digital technologies, (3) Teachers and teaching, (4) Design of learning environments and curricula, (5) Implementation of curricula and classroom practice, (6) Access, equity and socio-cultural issues, (7) connectivity and virtual networks for learning. The plan for the

Study Conference was that the participants would be divided among these themes based on their written submissions. However, two themes *Mathematics and mathematical practices* and *connectivity and virtual networks for learning* received rather few contributors. The limited interest in the former theme revealed a stark difference with the first ICMI study, which had been mainly concerned with the impact of technology on mathematical practice. With regard to the latter theme, it no doubt reflected the fact that rather little research had been done on this topic: the incentive behind organising the *connectivity* plenary panel. WE predict this will be a major research project in the future. Two other themes, important for the Study, *implementation of curricula and classroom practice* and *access, equity and socio-cultural issues* attracted slightly more contributions and we grouped the contributors in a single working group. Finally the participants were placed in four themes each focussing on the preparation of a section of the Study book(see below). Each working group was organised and chaired by members of the IPC. All the participants were invited to fill in evaluations of the Conference after the last session. These evaluations were uniformly positive; delegates appreciated this mixture of Working groups (with a clear agenda) and plenary sessions, a delicate balance that we believe we achieved.

Parallel regional workshop for teachers

Following a demand from local organizers and consistent with our special focus on developing countries, the IPC decided that teachers from the region would be encouraged to join the ICMI 17 for specific sessions: they were invited to attend all the plenary sessions of the Study along with a series of two-hour parallel presentations on the use of educational software. 6 sessions of 3 parallel laboratory activities were organized. This local activity was attended by 44 Vietnamese teachers, 3 teachers from Cambodia and 2 teachers from Thailand,

The participants' evaluation of this regional workshop was very positive. Beyond the interest of the academic activities *per se*, most participants pointed out that they had found invaluable the contacts they had established with the teachers from different institutions all over the region as well as with participants in the ICMI Study.

Proceedings of the Study conference

The proceedings of the Study Conference (clearly distinguished from the ICMI 17 Study Book), gathered together the written contributions of the invited participants and the abstracts of the plenary sessions. They were published in a booklet and also as a CD-Rom. [5]

The ICMI 17 Study Book

The production of the ICMI Study 17 Book is in progress and it is hoped that it will be published in 2008. Five chapters will be written from the plenary sessions and four sections A-D will incorporate the work of thematic working groups as summarised below. Each section is coordinated IPC members.

Section A. Implementation of curricula; issues of access and equity.

Discussion in this section started from the observation that access to, and use of, digital technologies differs between countries, and within countries, according to socio-economic, gender and cultural factors. Thus the group set out to try better to understand how cultural practices in technology-integrated mathematics enhance, or erode, equity and agency in mathematics education.

The section will be organised into four chapters

1. ***Implementation of technology-rich curriculum***
2. ***Access, equity and agency in/through technology-rich mathematics curriculum***
3. ***Factors influencing curriculum and practice***
4. ***Issues in reform and change***

Section B. Teachers and teaching.

This theme discussed how the integration of any new artifact into a teaching situation could be expected to alter its existing equilibrium and required teachers to undergo a complex process of adaptation, with modifications in the case of digital technologies, likely to be particularly pronounced. Various frameworks, drawing from both theory and practice, are currently employed to analyse the role of the teacher in orchestrating technology-integrated mathematics learning. The group considered the complementarities and contrasts between these frameworks and how they are operationalised in the face of ever-evolving resources. It also tried to address the implications of these complex issues for teacher professional development.

The section will be organised in four chapters.

1: Introduction
2: Learning to teach mathematics with digital technology
3: Working with teachers: context and culture
4: Theoretical perspectives and classroom implementation.

Section C. Learning and assessing mathematics with and through digital technologies.

This theme concentrated on developing understandings of how technologies might enhance or constrain the learning and teaching of mathematics, and the implications for assessment practices. Its foci included consideration of how digital technologies might be employed to open windows on learners' developing knowledge, and on how interactions with digital tools mediate learning trajectories. Additionally, the theme addressed the challenges involved in balancing the use of mental, paper-and-pencil, and digital tools in both assessment and teaching activities.

The section will be organised into six chapters.

1: Introduction
2: The integration of technology in mathematics education: what do theoretical perspectives offer?
3: Mathematical knowledge and practices resulting from access to digital technologies
4: Mathematical concepts and learning trajectories
5: Assessment supported by digital technologies
6: Collaborative work and communication: communities of inquiry, learning and practice

Section D. Design of learning environments and curricula.

This theme focussed on the issues and challenges involved in designing mathematics learning environments that integrate digital technologies, while recognising that the tools made available in such environments can and do shape mathematical activity in ways that to some extent are predicable and in some not. In addition to considering the specific affordances and constraints of different digital technologies for structuring mathematical learning experiences (including various software packages, hardware configurations and the Internet), this group considered the implications of design decisions on tools, curriculum, teaching and learning.

The section will be organised in four chapters.

1: Introduction

2: Designing digital technologies and learning activities for different geometries
3: Designing for mathematical engagement through modelling
4: Implementing technology at a national scale

Final note

This paper reports on a collective work not yet achieved so there is little point in a long conclusion. However we are confident that ICMI 17 will not only play a crucial role in and of itself, through its focus on developing countries and its presentation of challenges to be faced now and in the future, but also will complement ICMI 1 by partially filling gaps that have become apparent in the last few years, and by reflecting the evolution of the relationship between education and technology. We end by expressing our gratitude to the EC of ICMI for supporting us, and to the IPC members and participants for the excellent work before, during and after the Study Conference and continuing up to the publication of our book.

Annex

Members of the International Programmed Committee:

Prof. Celia Hoyles, London Knowledge Lab, Institute of Education, University of London, UK, co-chair

Prof. Jean-Baptiste Lagrange, IUFM de Reims, France, co-chair

Prof. Douglas Clements, Department of Learning and Instruction, University at Buffalo, US (up to August 2005)

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Prof. Bernard R. Hodgson, Département de mathématiques et de statistique, Université Laval, Canada (*ex officio*, Secretary-General of ICMI)

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