Topic Study Group 14

Teaching and Learning of Programming and Algorithms

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1. Teaching and Learning of Programming and Algorithms: A New TSG at ICME!

We see the introduction of this new TSG-14 as a response to the increased integration of programming and algorithmics in our school curricula around the world, sometimes within or in relation to mathematics. At the onset of this TSG, is undoubtedly the work and vision by pioneer Seymour Papert. We opened our TSG sessions by recalling the following quote from Papert's influential 1980 Mindstorm book, reminding us that although the broader integration of programming and algorithmics in our schools (compulsory programs) is rather recent, the vision had long been laid out:

> In many schools today, the phrase "computer-aided instruction" means making the computer teach the child. One might say the computer is being used to program the child. In my vision, the child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building. (Papert, 1980, p. 5)

2. Aim of the TSG

The aim of this new ICME Topic Study Group was to explore questions that raise from such a rapid and widespread interest of integrating programming and computational thinking in education and to exchange information about evolving trends and perspectives within various educational contexts from around the world. Questions and themes at centre of our interests were for example:

- What are the current realities of teaching and learning of algorithmics and programming in relation to school and university mathematics classrooms?

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- To what extent and how is research informing teacher education and practices to support the development of computational thinking?
- What theoretical perspectives and methodologies are relevant for studying the teaching and learning of programming and algorithms in relation specifically to learning mathematics and what theoretical or practical results have emerged? For example, what is the relation between mathematics (teaching and learning) and programming and algorithmics (teaching and learning)?
- What obstacles to integration have occurred and how have they been overcome?
- What affordances have been observed and how were they exploited?

To this end, we received and discussed research- and practice-based contributions concerning different levels of education (from elementary to university) and various topics related to the teaching and learning of programming and algorithmics, either in support of or as supported by the teaching and learning of mathematics. In the next section, we provide more details about the contributions that were presented and discussed.

3. Program Overview

1.1. Submissions

We received 17 submissions from 12 countries (South America: 1; North America: 2; Asia: 3; Europe: 5; Australia: 1), thus reaching our goal of diverse cultural representation. Of those 17 submissions, one was an invited long paper, five were accepted as long paper presentations for 2020 (3 were presented in 2021), seven as short paper presentations for 2020 (6 were presented in 2021), and three as posters for 2020 (1 was presented), and one was rejected.

1.2. Paper and poster presentation sessions

Each of our three sessions had a similar format: first an introduction by one of the TSG co-chairs of the themes and schedule for the session. It was followed by the oral presentations of (40-minute) *invited* talk (IT) or (25-minute) *long* papers (LO), (15 minute) *short* papers (SO), and the (5-minute) *poster* for the last session. We kept a 20 minutes time window at the end of each session for a collective discussion at which some guiding questions were provided as a way to prompt the conversation. We saw this discussion as critical to promote networking and to engage in deepening our understanding of different issues presented. We ended the last session by summarizing some key points that were raised during our three sessions, as well as highlighting some under-represented topics that should be part in future conversation.

Among the 16 accepted submissions, 11 of them were presented at the 2021 hybrid conference. We list these contributions and authors below in Tab. 1 in order of presentation:

Tab. 1: List of Contributions Presented

Paper and author(s)	
[1]	Algorithmic thinking: emerging implications for school mathematics education. ***Max Stephens*** (Australia) *and Djordje M. Kadijevich* (Serbia). (LO)
[2]	Mathematics education and computational thinking. ***Takuma Takayama*** (Japan). (SO)
[3]	Teachers' perceptions of computational thinking as part of the teaching of mathematics: a hermeneutic literature review. ***Camilla Finsterbach Kaup*** (Denmark). (SO)
[4]	Three important aspects of research on computational/algorithmic thinking. ***Djordje M. Kadijevich*** (Serbia) *and Max Stephens* (Australia). (LO)
[5]	On enumeration in mathematics and computer science: some didactical issues. ***Simon Modeste*** (France). (LO)
[6]	A framework for analyzing the integration of algorithms and programming into mathematics textbooks. ***Tran Kiem Minh****, Nguyen Thuy Viet Anh, and Tran Trong Ha* (Vietnam). (SO)
[7]	Working mathematically and thinking computationally: capitalising on commonalities for integrated teaching. ***Elena Prieto*** *and Kathryn Holmes* (Australia). (IT)
[8]	Modelling and 3D priniting a circular staircase for a doll's house: teaching computational thinking using a range of different tools. ***Gregor Milicic*** *and* ***Matthias Ludwig*** (Germany). (SO)
[9]	Researching the teaching and learning of programming for university mathematical investigation projects. ***Chantal Buteau*** (Canada)*, Eric Muller* (Canada)*, Ghislaine Gueudet* (France)*, Joyce Mgombelo* (Canada)*, Ana I. Sacristán* (Mexico). (SO)
[10]	"Math & CS Labs": a bi-disciplinary course for second-year undergraduates in mathematics or computer science. ***Antoine Meyer*** *and David Doyen* (France). (SO)
[11]	Matlab as a tool for experimental mathematics. ***Yevgeny A. Gayev*** (Ukraine). (Poster)

1.3. Conference themes

Each session focused on different themes. In the following, we list the themes of each session, together with selected guiding questions that were proposed in order to facilitate the discussion session. We see those questions pointing to particular interests from scholars and needs from practitioners in the area of teaching and learning of programming and algorithmics in mathematics education.

In the first session, we focused on the joint development in curriculum of mathematics and algorithmic/computational thinking; pedagogical approaches; and, attitudes and knowledge of (prospective) teachers. We noted that there is a historical and epistemological proximity between mathematics and computer sciences and questioned for example: *In what ways do or 'should' school mathematics curricula exploit this proximity? And is an understanding of this proximity necessary for teachers in order for them to meaningfully integrate algorithmic/computational thinking in their teaching of mathematics?* Furthermore, we wondered, due to the emerging integration in many curricula: *To what extent and how should research inform mathematics teacher education and practices to support the integration and assessment of algorithmic/computational thinking? What are the barriers and challenges experienced by teachers who are integrating algorithms and programming as part of their mathematics teaching? And which pedagogical approaches support students' learning of mathematics in a context with algorithms and programming?*

In this second session, we focused on two main themes, namely the conceptualization of algorithmic and computational thinking, and the interactions between computer science and mathematics and their potentialities in the teaching and learning of mathematics. Early on in our discussion, emerged the need to articulate a conceptualization of algorithmic thinking and computational thinking, and we wondered about its link(s) with: *problem solving, different types of mathematical thinking (in particular, algebraic thinking and statistical thinking), mathematical reasoning (logical thinking, argument, justification, generalisation), and design thinking*. We wondered about the *theoretical frameworks that can be relevant to study algorithmic/computational thinking for mathematics teaching and learning.* And we also asked questions, such as: *How does/should the computer science curriculum impact problem solving in mathematics?*

Finally, in this third and last session, we focused on the incorporation of algorithmic/computational thinking into mathematics curriculum at secondary school and university levels, as well as teaching practices and resources at these levels. Different aspects were discussed, such as the *kind of articulations between programing and mathematics activities that support the students' learning of mathematics and computer science concepts in the most efficient way.* We also questioned, for example, *which domains/subject areas that are the most fruitful basis for the integration of algorithmic/computational thinking in mathematics curriculum*; *and whether there are differences between integration of algorithmic/computational thinking in mathematics curriculum at high school and university levels.*

4. Future Directions (Areas for Future Research)

Different approaches that bring together the learning of programming and algorithmics with mathematics learning were discussed during the sessions, including multiple examples of activities, different models of integration in the curriculum, resources for teachers, and the identification of different areas of mathematics that are particularly fruitful. As we ended our TSG, we identified three under-represented topics in our conversation that we deemed as key to incorporate in future conversation, namely:

- Initial and professional teacher education
- Classroom realities of teacher and student practices
- Theoretical and methodological frameworks to analyse the above two

References

S. Papert (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.