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An introduction to TWG 15: Teaching mathematics with technology and other resources

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Introduction

The working group on teaching adopts a broad view of the use of *technology* resources in mathematics education to include math specific learning environments and general digital tools, both to teach mathematics in the class and to manage the professional issues to design activities, didactic methodologies, and assessment. Papers and posters were focused on different roles of teachers as educators, designers, learners, participants in communities... The main theories on the topic have been examined according to a structured viewpoint that connects each other (Sinclair et al., 2023).

Some contributions reflected on Covid-19 pandemic teaching (Klemer et al.; Segal et al.; Uygan & Bozkurt) and one has been awarded (Caputo, Cusi & Branchetti).

Organisation of TWG15 and its sub-themes

TWG15 accepted 34 papers and 8 posters for presentation at the conference, which reported research from 18 countries, with 46 participants of which 25 academics and 21 young researchers. The papers and posters have been presented in 6 sessions, and one session has been devoted to the preparation of the report. Papers and posters have been presented in groups of 3 to 5 and followed by a reaction and a discussion. A padlet collected all the presentations, reactions, and comments by participants.

The papers and posters have been pre-sorted and finally grouped into four sub-themes: *Teacher competencies, beliefs, and practice* (20 papers/posters), *Management of teaching with technologies* (10), *Assessment and the use of technologies* (5), and *Computational thinking* (7).

Sub-theme 1: Teacher competencies, beliefs, and practice

In this sub-theme we have brought together all the contributions that deal with both the cognitive and affective aspects of teachers' competencies, beliefs, and practices. These aspects were described for the different roles of teachers when teaching with technology. Teachers are learners to use new technologies for their teaching (such as 3D-printing – Blanco & Fernández-López), they are users of technology when designing their classrooms, e.g. using CAS in upper secondary level (Geil & Høsted) or using technology for problem-solving (Ovadiya; Gautam) or using digital mathematics tools to support discovery learning and multiple representations (Shen et al.). Teachers can also be designers of technology such as e-books (Almahdi et al.) or just participants in professionalization courses via technology such as MOOCs (Taranto et al.).

These different roles were touched in our papers focusing a wide range of manifold teachers' cognitive and affective competencies to teach mathematics with technology. Therefore, our discussions highlighted the importance of integrating and networking different frameworks for knowledge, competencies, and practice to inform Teacher Education Curricula and subsequently to support teachers' professional development and practice (see Rocha; Akkoç & Hangül; Botelho, et al.; Fabian). We saw the necessity of academics' designing of appropriate professional development resources (short courses and series of courses, diagnostic survey tools, etc.) and ongoing support for teachers (e.g. communities of practice and co-designing) to ensure effective professional development that also aligns with the challenge of the constantly evolving technologies and to prepare teachers to integrate the different types of technology usable for teaching mathematics. The design and use of resources can be made also by teachers, and the study by Baştürk Şahin and Tapan Broutin examines a novice teacher engaged in this task, to enhance students' mathematical competencies. Moreover, Brödner et al. present a decision theatre as a problem relevant to society as a social-methodological setting where a problem relevant to society as a whole from the non-mathematical world is translated into mathematics and prepared to be discussed productively in the non-mathematical world, e.g., a Mobility Transition Model to solve the problem of CO emission.

Looking to the future it is very promising, that teachers' beliefs according to teaching mathematics with technology is evolving with a positive sense of self-efficacy (Shen et al.). Especially the experiences of remote teaching during the COVID-pandemic led to an increase of using technologies in mathematics teaching (Klemer et al.; Segal et al.). This effect could be reinforced by the fact that the use of technology is getting easier together with new opportunities for PD such as initiating teachers self-learning (e.g. Neogrády-Kiss et al.), more sustainable programs (Pimenta et al.) and a new way of interactions (e.g. in an asynchronous way, Caputo et al.).

Sub-theme 2: Management of teaching with technologies

This sub-theme considers research about managing teaching with the use of technologies. Amongst all reported research, use of the instrumental orchestration model was prominent to develop or describe teaching practices. While two papers focused on developing pre-service teachers' use of technology through micro teaching practices (Alan & Akkoç; Bozkurt & Yiğit Koyunkaya), one paper defined online instrumental orchestration types applied during a teaching experiment under the conditions of emergency remote teaching during the COVID 19 pandemic in an initial teacher education setting (Uygan & Bozkurt). There was more research reported similarly investigating teachers' management of technologies in teaching from the perspective of different frameworks. For instance, distance learning arrangement was also examined from the students' perspective in Finnish upper secondary schools, considering communication, independent work, and technology utilization during the COVID-19 pandemic (Sydänmaanlakka et al.). Additionally, some papers reported findings regarding teachers' ability to design and making manipulatives for mathematics teaching such as inquiring into digital fabrication tools, techniques, and platforms for in-service mathematics teachers (Stigberg et al.), developing pre-service teachers' pedagogical content knowledge about the use of 3D-printing (Läufer & Ludwig) and the didactical suitability of using 3D printing and augmented reality for pre-service mathematics teachers (Blanco & Fernández-López). Cross-curricular approaches were also incorporated, such as the example of Lyublinskaya & Cabral, which

combined art-based practices in the frame of understanding of geometric transformations. Another study by directly focusing on in-service mathematics teachers' practices, examined teachers' actions, interactions, and collaboration to develop their understanding of the diverse approaches around the design and didactical use of a digital medium for mathematics teaching (Diamantidis & Kynigos). Finally, Haspekian & Kieran presented the construct of "instrumental distance" to shed light on deep obstacles to technology integration in mathematics education, providing examples to improve the integration efforts.

Sub-theme 3: Assessment and the use of technologies

This subtheme comprises the contributions by MacMahon & Lyublinskaya, who propose a theoretical framework for secondary mathematics Technology Enhanced Formative Assessment (TEFA) literacy and an analytic rubric for TEFA Literacy. Speer & Eichler present a case study that shows how a carefully designed course on 'Digital tasks' can support the development of pre-service teachers' competencies for designing suitable assessment tasks (in STACK), including targeted and timely feedback to learners. Geraniou & Bretscher present a prototype survey for assessing teachers' MDC using a vignette approach. Ukkonen investigated the formative assessment practice of the teacher and illuminated some of the practices that can contribute to the successful integration of CT in mathematics. Capone et al. investigate mathematics teachers' experience with a hackathon aimed at designing a digital game. They show that teachers ask themselves how to assess the students and if a digital game can be an assessment tool. As evidenced by these papers, different researchers use different concepts to describe the knowledge/skills/competencies that are needed by teachers for assessment with digital technology. While MacMahon & Lyublinskaya propose the concept of "TEFA literacy", Speer & Eichler refer to "digital competencies" while Geraniou & Bretscher refer to the construct of "MDCT"—mathematical digital competencies for teachers. It would be valuable for future research to discuss connections and distinctions among these constructs with respect to assessment with technology. In the discussion following the paper presentations, it was highlighted that also clear learning goals are always indispensable for sound assessment.

Sub-theme 4: Computational thinking (CT)

The subtheme is about CT in mathematics education, including programming practices. Løken et al. examine the views of pre- and in-service teachers regarding programming integration in Norway. Results reveal lack of programming experience affect teachers' confidence. Yunianto et al. present how spreadsheet-based CT lessons enhance understanding and problem-solving practices for pre-service teachers, by emphasizing the uselessness of spreadsheets in facilitating comprehension. Russo et al.'s poster concerns the gamification in mathematics education by discussing pupils' engagement and motivation, while Branco & Colaço present a didactical proposal to explore the intersection of CT and mathematics and how prospective primary teachers improved their performance. Mathisen et al. explore the connections between CT and mathematics in Norwegian curricula, using BlueBot in the context of irrational numbers, or angles and shapes. Engelhardt et al. explore the competence required to use dynamic worksheets for enhancing functional thinking of pre-service teachers. Fadum & Tellefsen focus on Norwegian teachers' beliefs about collaborative learning through programming in grades 5 to 10. The discussion on the papers pointed out a few *key* challenges: teacher engagement,

teachers' competence and teacher PD regarding CT, assessment of CT, bridging CT and mathematics and the most important one as different and diverging understandings of CT in the literature.

Emerging topics and future issues of the TWG15 community

Some final remarks on future issues - emerged by papers and discussions - are presented though and across the sub-themes. For the future, it is important not only to inform teachers about the wide range of relevant technologies for teaching and learning mathematics, but also to professionalise them in their competencies for the meaningful use of these different technologies. New approaches like learning from other cultural approaches in PD is meaningful (e.g. Robutti & Bini) as well as new ways through new technologies from outside of mathematics (i.e. games, programming, decision theatre). It would be helpful to integrate frameworks and technologies from general education, sociology and psychology to be used in PD (e.g. Bakos; Weinhandl et al.). Another important issue is investigating new orchestration types that consider the technological knowledge of the students, so reducing the gap between researchers in mathematics education, developers of technologies, and teachers (possible enlargement of the theoretical framework of meta-didactical transposition). Also, although it is promising as remote teaching increase the use of technologies amongst teachers, it raises a new awareness about sociocultural and classroom norms (new teachers' role and new students' role, co-orchestration should be considered) (Uygan and Bozkurt; Sydänmaanlakka et al.). A promising issue for future is to consider students' ability to be autonomous learners with different types of assessment, in technology-enhanced formative assessment for mathematics and how to use assessment in gamification, programming, computational thinking, etc. to increase student outcomes, motivation, engagement, and interest.

Emerging technologies as Artificial Intelligence, Virtual Reality, Augmented Reality and others have been discussed as possible contexts and tools in which creativity, imagination, critical abilities, mathematical and interdisciplinary competencies of students and teachers can be used, supported, and enhanced in education, both individually and in communities of practice.

In order to consolidate a community working together in continuity from CERME12 to CERME13, the Team of TWG15 (with TWG16) organized 3 online seminars before the congress in Budapest, and will do the same before Bolzano, 2025. The seminars aim at maintaining the collaboration among scholars and to inform them on new results in mathematics education research in relation to TWG15.

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