Mathematics Education in Times of Exponential Change: New trends and new debates

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Introduction

At the time of writing this introduction, the world is dealing with the aftermath of a terrifying pandemic crisis. This crisis has affected teaching and learning practices and scientific activities in all fields, including in mathematics education. CERME12, in 2022, took place a year later than scheduled as a virtual conference and in difficult conditions, and it was made possible only by the dedicated engagement of the International Programme Committee, the Local Organising Committee and the Thematic Working Groups' leaders. In the plenary session of the congress, Jeppe Skott emphasised that the mathematics education community should remain modest in what could be expected from the scientific reports at the conference due the extreme conditions in which teaching and learning had happened in the previous two years. In the same plenary Susanne Prediger added that our community should nevertheless be very ambitious and strive to progress in the advancement of mathematics education. For the new generation of researchers in mathematics education, these encouraging words coming from experienced colleagues meant searching for a balance between maintaining reasonable expectations of the work that could be done in such circumstances and dealing with the challenges of the present. But what does this mean for research about digital technologies in mathematics education? Not only this issue is so complex, but the pandemic forced a shift to modes of teaching and learning that involved much reliance on digital technologies, therefore making research in this area very topical. If the last decade of research was labelled by our community as "Mathematics Education in the Digital Age" (e.g., Clark-Wilson et al., 2021) how could the current times be described? Some authors criticise the speed of the change in the use of digital technologies and describe our era as "Education in the Automated Age" (Andrejevic, 2019) to emphasise the automated generation of large datasets coming from data science and machine learning, without really focusing on what the implications could be on teaching and learning. Could the next decade be described as "Mathematics Education in Times of Exponential Change"? Taking a humorous view of this 'brand name', it contains the word "exponential", which is related to a sophisticated mathematical concept of exponential functions. One outcome of the pandemic crisis was to make clear that the development of pandemics cannot be understood without mathematics. In this sense, the inclusion of a mathematical word such as 'exponential' in the label is well deserved. The unexpected and necessary developments of the use of technologies for teaching and learning mathematics are the topic of the ERME Topic Conference MEDA3 in Nitra, Slovakia, which was held in September 2022.

Thematic and organizational aspects of MEDA3

MEDA3 is a natural continuation of the previous two conferences in 2018 (Denmark) and 2020 (remotely, Austria) where the ERME community gathers to discuss applications of digital technology in mathematics education from cross-disciplinary and interdisciplinary perspectives. Of course, this

does not mean that the use of traditional technologies, resources, and artifacts is neglected, those are used alongside new ones. Indeed, the contributions to this conference address the applications of new tools and well-established tools to the learning and teaching of mathematics, offering much richness of educational experiences. In the call for papers to be submitted to the conference we outlined three themes (Table 1) around which we wished to encourage contributions. Of course, we were aware that many other important issues exist for digital technologies, but we envisaged these three themes to be probably the most relevant to the current use of digital technologies.

Table 1: Overview on the number of conference contributions per theme

Theme	Total number of accepted contributions
1. Mathematics teacher' practices, teacher education and professional development in the digital age	18
2. Curriculum innovation, design of digital and hybrid environments and practical implementation of digital resources	33
3. Assessment in mathematics education in the digital age	6

In what follows we outline the three themes and the nature of the contributions received to each one.

Mathematics teacher' practices, teacher education and professional development

Adoption of digital tools into classroom practice takes time and the tools and functions of digital technologies change rapidly. The COVID-19 pandemic affected teachers' practices, experiences, and their processes of adaptation of new tools. To better understand these new processes, new approaches and emerging frameworks are needed to guide teachers to integrate digital tools into mathematics education on the one hand, and to ensure professional development of mathematics teachers on the other. Teachers' expectations regarding perspectives for teaching after the crisis vary, depending on several factors. Contributions to this theme focus on teachers' self-learning in formal and informal settings, use of shared virtual/hybrid spaces and resources for teacher education and professional development, working in clouds and wiki, but they also address other concerns. Specifically, the theme includes several examples of teacher practices with digital tools in the pandemic, an analysis of virtual learning environments to support teacher practices, and practices of (block-based) programming in professional development of pre-service mathematics teachers.

Curriculum innovation, design of digital and hybrid environments and practices with digital resources

Applications of Learning Management Systems (LMS) in the teaching and learning of mathematics, but also uses of Learning Analytics (LA) and Artificial Intelligence (AI) in the research activities about mathematics education, have intensified since the pandemic outbreak. Although their effects are closely connected to the design of digital curriculum resources for mathematics or synchronous and hybrid activities in mathematics education, these scientific disciplines are seldom considered in connection to learning theories and the didactics of mathematics. Exploring these connections allows us to understand the effects of automated and adaptive learning environments to self-regulated learning and individualization of learning trajectories through collaboration (Donevska-Todorova, 2022). Contributions to this theme focus on the design and implementation of resources with novel technologies, such as 3D print technologies or virtual and augmented reality, in addition to the well-established digital geometry systems (DGS) and computer aided systems (CAS). Other papers discuss

issues concerning computational thinking in mathematics education at all educational levels, as well as different modalities of synchronous and asynchronous learning supported with various digital tools.

Assessment with digital technologies in mathematics education

The impact of assessment with digital technologies on teaching and learning mathematics has been wide-reaching and has touched all aspects of assessment practices in the classroom – both for formative and for summative assessment. Yet little is still known about the effects of introducing assessment with digital technologies on students' learning and on students' and teachers' experiences. As an example, for the case of computer aided assessment (CAA) Kinnear et al., (2022) drew a rich research agenda highlighting the areas which are still under-research in this field – of which there are many. Moreover, the pandemic forced teachers to use digital tools also for marking traditional written output, and the impact of this new development on how feedback is written (by the teachers) and received (by the students) has not been well understood yet. We received six papers regarding the use of digital technologies for assessment. Topics within this theme go from the use of CAA for formative assessment and especially on the topic of example generation, to true/false questions design and generally the design of digital tasks, to the impact that the digital medium has on the type of feedback teachers give students.

Conclusions and Prospects

There has been a change in working with and thinking about digital technologies in mathematics education in the last years and decades. Up to the beginning of the millennium the research emphasis was firmly on the use of computer algebra systems, dynamic geometry systems and spreadsheets. Research focused on the affordances of such tools and possibilities for concept formation, on the likely changes of contents of mathematics and on the possible new ways in which mathematics could be taught in mathematics classrooms if these digital technologies were used. Since 2010 the emphasis concerning digital technologies had been more on learning environments, adaptive systems, virtual reality, augmented reality, videos, 3-D-printing, formative and summative assessment systems, and ebooks. The papers presented at MEDA3 are a representation of this development. Of course, key competences like functional thinking, computational thinking, proving, representing, or modelling and their interaction with digital technologies are still important. However, they are now seen in the frame of learning and teaching systems. The pandemic gave an additional push to this development.

The great variety of contributions to the MEDA3 conference, also concerning different school types and pre- and in-service teacher education, show the challenge to bring together the "old" ideas of working with digital tools (like CAS or DGS), the still important key competences and the "new" ways of working with software systems on laptops and smartphones. They also show the necessity to describe these new ways of working with new or newly interpreted concepts like digital competences, digital resources, digital design, diagnostic tools, dynamic communication, or computational thinking. MEDA3 is one step in moving ahead to understand better the interrelationship between mathematics and the new digital technologies.

Discussion about these themes continues in relation to the Call for Papers for a Special Issue in the Springer International Journal for Research in Undergraduate Mathematics (IJRUME), "Digital Experiences in University Mathematics Education. Advances and Expectations", that will be edited by Ana Donevska-Todorova, Eleonora Faggiano, Janka Medová, and Melih Turgut and a special ZDM-issue "Mathematics Education in the Digital Age", edited by Hans-Georg Weigand, Michal Tabach and Jana Trgalova.

References

Andrejevic, M. (2019). *Automated media*. New York and Abingdon: Routledge.

Clark-Wilson, A., Donevska-Todorova, A., Faggiano, E., Trgalová, J., & Weigand, H. G. (Eds.). (2021). *Mathematics Education in the Digital Age: Learning, Practice and Theory*. Routledge. https://doi.org/10.4324/9781003137580

Donevska-Todorova, A. (2022). Individual, but not alone! Design of individual and collaborative activities for adaptive learning pathways in learning management systems, *INTED2022 Proceedings*, pp. 8890-8897. doi: 10.21125/inted.2022.2319

Kinnear G., Jones I., Sangwin C., Alarfaj M., Davies B., Fearn S., Foster C., Heck A., Henderson K, Hunt T., Iannone P., Kontorovich I., Larson N., Lowe T., Meyer J., O'Shea A., Rowlett, P., Sikurajapathi I and Wong T. (2022) A collaboratively-derived research agenda for e-assessment in university mathematics. *The International Journal of Research in Undergraduate Mathematics Education*. https://doi.org/10.1007/s40753-022-00189-6