Introduction to the papers of TWG 16: Learning mathematics with technology and other resources

Paul Drijvers, Eleonora Faggiano, Seçil Yemen Karpuzcu, Florian Schacht, Nathalie Sinclair, Osama Swidan

Introduction to the papers of TWG 16:
Learning mathematics with technology and other resources

Paul Drijvers[1], Eleonora Faggiano[2], Seçil Yemen Karpuzcu[3], Florian Schacht[4], Nathalie Sinclair[5], Osama Swidan[6]

[1]Utrecht University, the Netherlands; p.drijvers@uu.nl

[2]Università di Bari Aldo Moro, Italy; eleonora.faggiano@uniba.it

[3]Kütahya Dumlupınar University, Turkey; secil.karpuzcu@dpu.edu.tr

[4]Universität Duisburg-Essen, Germany; florian.schacht@uni-due.de

[5]Simon Fraser University, Canada; nathalie_sinclair@sfu.ca

[6]Ben-Gurion University of the Negev, Israel; osamasw@gmail.com

Abstract: This short contribution summarizes the results of TWG16 according to the five themes described in the Call for papers. As an overall conclusion, we notice that the somewhat general theme of good practices in technology-rich mathematics education attracts much attention, whereas the other themes apparently are addressed to a lesser extent in our research community, with the impact of digital technology on research methods as the most striking underrepresented example.

Keywords: Digital technology, embodiment, good practice, mathematics education.

Overview of themes and contributions

The scope of thematic working group TWG16 was to address opportunities and constraints of digital technology and other resources for students' learning of mathematics; a topic that is all the more relevant in times of an immense increase of distant learning and teaching practices. As a targeted outcome, we wanted to establish an overview of the current state of the art. We also aimed to suggest important trends for technology-rich mathematics education in the future, including a research agenda. TWG15 addresses a similar global topic but focuses on teaching rather than on learning.

Table 1: TWG16 themes and contributions

Theme	# accepted papers	# accepted posters
1. Theoretical advances on using digital technology in mathematics education	5	1
2. Embodiment and the use of digital technology in mathematics education	4	0
3. New roles for new tools (e.g., augmented and virtual reality, 3D printers)	5	1
4. Good practices in technology-rich design, learning and assessment in mathematics education	15	5

5. The impact of digital technology on research methods	1	0

The TWG16 call for papers identified five main themes to be addressed. Table 1 provides an overview of these themes and of the number of contributions per theme. Altogether, we had 30 accepted papers, 7 accepted posters. Some 60 participants from many countries within and outside Europe took part in the sessions, and contributed to having a positive and productive atmosphere.

Main results per theme

Theoretical advances on using digital technology in mathematics education

The crucial role of theory was an important issue within various discussions, not only limited to the contributions specifically addressing this theme. To a great extent this is due to the interconnectivity of the different themes. For example, innovative contributions focusing on embodiment or implementing new tools suggest a need for suitable theoretical frameworks to design and reconstruct mathematical learning activities. The contributions specifically addressing theoretical advances took particular aspects into account. On the one hand, some of the contributions addressed the value of theoretical frameworks when working with digital tools. In terms of extending a theoretical framework with regards to the use of digital tools, the potential of Cultural Historical Activity Theory (Engeström, 2000) was discussed in the context of programming activities. In terms of methodological considerations, the use of an instrumental approach in a quantitative study on functional thinking was explored. The role of an epistemological approach to inclusive settings using digital tools provided another theoretical lens. On the other hand, some contributions showed the need to develop new theoretical frameworks in the context of using digital technology. For example, a framework for creating heuristic videos to enhance students' modeling competencies was presented, as well as a model for learning about black boxes. Both the contributions and the discussions show that the key role of theory as well as theoretical advances keeps being a central theme for TWG16.

Embodiment and the use of digital technology in mathematics education

This theme included a range of papers, with some focusing specifically on embodiment—in terms of theorizing it—and others only evoking the role of the body in mathematical meaning-making. In the latter case, one study considered the dynamic animations created by students using geometric transformations. Although the conceptual focus here was on creativity, the analysis of the expressive and aesthetic dimensions of the students' work could certainly relate to theories of embodiment that account for the role of the senses in mathematical thinking. In the former category was a contribution that focused explicitly on embodied design. It explores a possible alignment between Abrahamson's embodied design (Abrahamson et al., 2020) and Sfard's (2008) commognitive approach, proposing the perception-actions that could correspond to saming, encapsulating, and reifying. A second example taking an explicit theoretical stance was on enactivism. The researchers compared the finger gnosis deployed in two digital technology settings, TouchCounts and Rakin, studying the fingers movements of a child as they relate to number sense. Finally, a systematic literature review was presented on the embodied approaches to functional thinking involving the use of digital technology. This paper leverages a particular approach to embodiment arising again from the work of Abrahamson (e.g., see Abrahamson et al., 2020).

Overall, it was remarked that the theories of embodiment used tended to be focused on the individual learner and their intact bodies, conceptualized as ontologically distinct from the environments (including the digital tools). This contrasts with approaches to embodiment that are more distributed, socially situated and politically inflected.

New roles for new tools

The thematic working group discussed the use of innovative digital tools in mathematics classrooms. The participants discussed specifically the use of augmented reality, robots, and 3D printers. The contributions evidence how such digital tools affected students' learning and teachers' instruction. In particular, the researchers presented studies that showed how such tools shape the students' language, formulation of mathematical concepts, and shed light on robust teaching. In addition, participants discussed how these new tools may invite negotiation of the mathematical meanings embedded in the tools and the learning environment. A comparison of physical objects, common-use digital technologies, and new digital tools was also presented. Most of the contributions to this theme were qualitative studies conducted with few participants. This fact required the participants to consider the feasibility of implementing these new digital tools in regular classrooms. Without any doubt, scaling up the use of such digital tools to regular classrooms will bring new opportunities and challenges for the learning and teaching of mathematics, and little is known about them yet. This may open a window toward a new research trend that will include questions on how to implement new tools in teaching practice. How should students engage and interact with such new tools? How will teachers' practices change through using such digital tools? This theme, of course, is far from having final answers, and seems suitable to revisiting during next CERME conferences.

Good practices in technology-rich design, learning and assessment in mathematics education

Developing good teaching practices that foster mathematics learning through technology-rich student activity is a prominent issue, all the more in times of emergency remote teaching due to the pandemic. Contributions describing good practices focused on topics such as the flipped classroom and distance learning environments, more established tools such as GeoGebra, tools for computer programming. Also, more innovative tools were used, such as a digital spirograph and the online application GeoGebra classroom. From the discussions we conclude that new pedagogies and practices have emerged in practices of using various digital tools, such as practices of digital-collaborative learning. It has become clear that the teachers' instrumental genesis of teachers is a prerequisite for good practice. Also, the availability of advanced digital technology used in the learning process questions the regular curricular goals. A main idea that emerged from the discussions is that good practices should use digital technologies to deepen mathematics learning through in-depth meaningful learning trajectories (teaching sequences), rather than through superficial tool use. To do so, new theoretical approaches might be needed. Another important conclusion was that social-media norms may change to enable new pedagogies to be put into practice. Finally, as our experiences with and knowledge of emergency remote learning with digital tools has drastically increased during the pandemic, we wonder how to capitalize on this in the future.

Many contributions in this theme presented examples of well-designed good practices. However, describing and investigating good practices also resulted in raising the issue of design principles. It

was pointed out that design is group work, with different types of expertise involved, and that it is usually done in cycles. There is a need to identify overarching design principles, and theories that can underpin them, both for the design of tools and environments and for the design of learning activities. Moreover, the sustainability of such design principles was recognized as a key point, as they need to be still applicable—maybe in adapted form—when new, more advanced digital tools will emerge.

The impact of digital technology on research methods

Many types of digital technology impact on our work as educational researchers. We have eye tracking, video labs, data logging, learning analytics, machine learning, software for qualitative data analysis, and artificial intelligence, to mention just some. Even if the TWG team felt the need to address the question of how these tools affect our research methodologies, we hardly received any contributions to this theme. Apparently, this is not (yet?) a 'living' topic in our community. We wonder whether this will change in two years, if the new TWG team takes up this theme once more.

Conclusion

A first goal of this TWG was to provide an overview of the current state of the art in the domain of technology-rich mathematics learning. Based on the contributions and discussions, we conclude that the field is moving quickly, and that much attention is paid to the design, implementation and evaluation of good practices for mathematics learning and teaching using digital technology. The need for further foundations, in terms of theoretical frameworks—being new or adaptations of existing ones—and design heuristics is widely recognized. However, the suggested themes that aim at such foundations received not many contributions. This may be partly caused by the impressions that the TWG attracted many relatively early-career researchers, with seniors being somewhat underrepresented. As a practical feed-forward for CERME-13, particular attention might be paid to ensuring a balanced group of participants in terms of seniority.

A second goal was to identify a research agenda. Even if this was touched upon only implicitly, the above theme reports provide an interesting picture: whereas the need for theoretical foundations is widely acknowledged, the themes on theoretical approaches, new tools, embodiment, and new research methods were not popular in terms of numbers of contributions. One of the challenges for the next edition, therefore, is to reiterate these themes and ensure a more explicit place for them in the call for papers. The number of participants in the CERME-12 group shows that the field is alive and the topic is attracting much attention by researchers. The distribution of contributions over themes shows that there is a clear research agenda: let's work on these theoretical and innovative foundations to ensure progress in these directions for the next edition.

References

Abrahamson, D., Nathan, M. J., Williams-Pierce, C., Walkington, C., Ottmar, E. R., Soto, H., & Alibali, M. W. (2020). The Future of Embodied Design for Mathematics Teaching and Learning. *Frontiers in Education, 5*(147). https://doi.org/10.3389/feduc.2020.00147

Engeström Y. (2000). Activity theory as a framework for analyzing and redesigning work. *Ergonomics, 43*(7), 960–74. https://doi.org/10.1080/001401300409143

Sfard, A. (2008). *Thinking as Communicating: Human Development, the Growth of Discourses, and Mathematizing*. Cambridge University Press. https://doi.org/10.1017/CBO9780511499944