Topic Study Group 25

The Role and the Use of Technology in the Teaching and Learning of Mathematics at Lower Secondary Level

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ABSTRACT Topic Study Group 25 (TSG-25) on the role and the use of technology in the teaching and learning of mathematics at lower secondary level discussed this topic over four sessions. These sessions focused on diverse topics such as immersive learning environments in the second session topics as self-efficacy, use of digital technologies outside the classroom and pedagogical aspects of using digital technologies were discussed. In the third session we discussed cultural aspects of technologies in the classroom, and in the last session we discussed communication and the mediating role of digital technologies. The group had contributions from all continents (apart from Antarctica), with a slight overweight of the contributions from European countries. The contributions consisted of five long papers, 21 short papers and eight posters

Keywords: Digital tools; Technology; Immersive learning; Computational thinking.

1. Themes and Description

Topic Study Group 25 (TSG-25) on the role and the use of technology in the teaching and learning of mathematics at lower secondary level was focused on three interrelated themes: (1) Technology in lower secondary education as a scientific endeavor. (2) The role of technologies in the teaching and learning of mathematics, and (3) Teacher in- and pre-service training with technologies or as a reply to new demands of technologies.

The work departed in an acknowledgement that technology and mathematics has a huge and increasing influence on many aspects of society, and hence that the educational attendance to the combination of mathematics and technology is of paramount importance.

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1.1. Technology in lower secondary education as a scientific endeavor

The focus on technology in lower secondary teaching as a scientific endeavor was initiated in order to frame a theoretical and methodological discussion. The concern being that several theoretical constructs and methodological approaches have been applied and developed in order to investigate the role of technology in mathematics learning, as well as in teachers' difficulty to integrate them. But these are somehow compartmentalized in local theoretical traditions. Networking of theories and the development of shared knowledge and methodologies are important, and in the group, we were trying to cross internal barriers and build a paradigmatic organization.

1.2. The role of technologies in the teaching and learning of mathematics

The range of technologies that suggest themselves to the mathematical classroom is wide and expanding. Some technologies come in relatively stable form (such as calculators spreadsheets and physical manipulatives), while others are in rapid flux (intelligent CAS tools as Wolfram Alpha, Applications within Virtual Reality and programming languages are examples of this). Some are specifically designed for school mathematics teaching (such as GeoGebra), some have been imported from business area (such as spreadsheets). These technologies influence the teaching and learning process in mathematics, in ways that have been studied by research for the last three decades, and continue to generate results.

1.3. Teacher in- and pre-service training

The discussion of what mathematical knowledge, skills and competence that technological development requires, or favors reaches decades back to the introduction of handheld calculators in schools, but more recently the rapid digitalization of the social and economic spheres is increasing the demand for students to develop algorithmic and computational competences. Technologies and digital tools are of growing importance to all educational systems and call for teacher training. For this reason, there is an ongoing research interest in the field of professional development of teachers using technology. Even if evidence-based methodologies can tell us whether these tools are succeeding and should be introduced in pre-service teacher education, it remains still the question of the transferability of successful experiments and, more generally, that of how to train teachers to integrate these technologies in their practices. In the Topic Study Group we had the possibility of taking a genuine international audience and perspective on this important issue.

2. Overview of the Program and the Sessions

The four sessions where thematically organized and ran in sprints with 2–5 presentations followed by a shared discussion.

2.1. First session

In the first session we discussed technologies that somehow changed the learning environment through immersive artifacts such as augmented and virtual reality, game-based learning and simulations, but also by a combination of historical sources and digital tools as well as other ways of bringing CAS and DGS into students mathematical reasoning.

Session one contained the opening, followed by two long oral presentations (LO, each 10 minutes) and a shared discussion of the two papers (also over 10 minutes). After a break the session continued with three short oral presentations (SO, each of eight minutes), and a shared discussion of these papers. Following one more break five posters where presented and discussed (Tab. 1).

Session one had many and rather diverse contributions. In the discussions it became clear that even though trends as game-based learning, virtual reality are both new and important to the teaching of mathematics it also makes sense to consider the pedagogical situations that these tools can lead to in continuity with other aspects of mathematics education, such as organization and implementation, and the use of history and cultural artifacts. In this session we also aimed at establishing a collaborative atmosphere.

Tab. 1. List of papers presented in Session1

	Paper/Poster and author(s)
[1]	An immersive learning experience for teaching equations equation lab. ***Morten Elkjaer*** *and Lui Albaek Thomsen* (Denmark). (LO)
[2]	Student's autonomy and digital technologies: collective documentation work in preservice teacher education. ***Ghislaine Gueudet*** *and Sophie Joffredo-Le Brun* (France). (LO)
[3]	Using augmented reality technology for instructional media in mathematics education. ***Shiwei Tan*** (China). (SO)
[4]	Mediations and rules when working with the interplay between original sources and GeoGebra. ***Marianne Thomsen*** (Denmark) *and Uffe Thomas Jankvist* (Afghanistan). (SO)
[5]	Developing spatial skills in a virtual reality environment for carpentry apprentices. ***Sylvia Van Borkulo*** *and Paul Drijvers* (The Netherlands). (SO)
[6]	Application of GeoGebra in the function study: the use of ICT in teaching mathematics. ***Wesley Matheus Moura Balbino****, Medeiros de Oliveira, and Francismar Holanda* (Brazil). (Poster)
[7]	EVA: an educational tool to simulate evacuations of buildings. ***André Greubel*** *and Hans-Stefan Siller* (Germany). (Poster)
[8]	Perspectives on the use of ICT in the high school mathematics classrooms. ***Erin Herz and George Ekol*** (South Africa). (Poster)
[9]	Role of ICT to enhance mathematics teaching. ***Santosh Paudel and Binaya Bhandari*** (Nepal). (Poster)
[10]	The mathema kids research seed: a GeoGebra youth club that tells stories. ***Carlos Eduardo Leon and Jefer Camilo Sachica-Castillo*** (Colombia). (Poster)

2.2. Second session

Session 2 addressed key elements relevant to the use of digital technologies from a scientific perspective — subject knowledge, self-efficacy, use of digital technologies outside the classroom and pedagogical aspects of using digital technologies.

All these issues are highly relevant and can have a lasting positive or negative impact on the use of digital technologies. Therefore, effectiveness research, subject knowledge testing and pedagogical measures to understand the content are enormously important. In this session we discussed these topics through two long oral presentations (LO, 10 minutes each) and 4 short oral presentations (SO, 8 minutes each) and discussed in detail future research possibilities (Tab. 2).

Tab. 2. List of papers presented in Session2

Paper and author(s)	
[11]	Instrumental orchestration with dynamic geometry: A Chinese case study. ***Fangchun Zhu*** (China). (LO)
[12]	Gray-boxing as a means for mathematical communication. ***Cecilie Carlsen Bach*** (Denmark). (LO)
[13]	Desmos App in the mathematics classroom: limitations and potentialities. ***Jair Dias de Abreu*** *and Silviano de Andrade* (Denmark). (SO)
[14]	Augmented reality for outdoor modeling tasks: bridging real problems with mathematical concepts. ***Adi Nur Cahyono****, Yulius Leonardus Sukestiyarno, Mohammad Asikin and Matthias Dieter Ludwig* (Indonesia). (SO)
[15]	Micro-teaching of landmark jobs fostering self-efficacy for teaching mathematics with technology. *Daniel Thurm and* ***Baerbel Maria Barzel*** (Germany). (SO)
[16]	Digital competency found by prospective secondary teachers according ontosemiotic approach. ***Joaquin Gimmenez****, Silvia Carvajal, and Vicenç Fon* (Spain). (SO)

2.3. Third session

Session 3 had focus on different cultural influences on different cultures and countries approaches to teaching mathematics with technologies. Case studies from China, France, India, Mexico and Denmark, and the ways that different school cultures and local policies was in interplay with the pedagogical possibilities and difficulties of various tools and technologies. We also discussed the way that cultural artifacts such as historical sources, buildings and museums can be used to enhance teaching and learning of mathematics and how digital tools can be instrumental in that respect. The session included presentation and discussion of two long papers (LO, 10 minutes for each presentation and 10 minutes for a shared discussion), three short papers (SO, presented for eight minutes) and a short presentation of a poster. These four contributions were discussed jointly (Tab. 3).

Tab. 3. List of papers and poster presented in Session 3

Paper and author(s)
[17] The development of technological craft knowledge within a community of inquiry. ***Ahlam Anabousy*** *and Michal Tabach* (Israel). (LO)
[18] Mobile learning of mathematics with apps for math trails. ***Ana Donevska-Todorova*** (Germany). (LO)
[19] Media, cognition and assemblage perspectives on ict in education: a three-part study in an indian school. ***Prateek Shah****, Harshit Agrawal and Sanjay Chandrasekharan* (India). (SO)
[20] Evolution of teaching practices with ICT: a case study with scratch in the French new mathematics curricula. ***Mariam Haspekian*** (France). (SO)
[21] Connecting conjectures and proof using dynamic geometry environments and a toolbox puzzle approach. ***Ingi Heinesen Hojsted*** (Denmark). (SO)
[22] Technology in classroom: a report of 3 researches. ***Alejandro Miguel Rosas Mendoza*** (Mexico). (Poster)

2.4. Fourth session

In session 4 we departed in the fact that effective use of digital technology inevitably leads to the mediating role of it. This is not only about how digital technologies are used in the classroom, but also about how digital tools enable or change interaction between teacher and learner. This consideration is not new in the discussion of digital technologies, but it is precisely through the use of new technologies and through the linkage with other process-related activities that this perspective continues to gain attention and contains sufficient research potential.

In the fourth session, which just put the scientific perspective on the mediating role of technology, 7 short-papers (SO) for 8 minutes each and 1 poster in the duration of 3 minutes were presented. An extensive discussion in the group rounded off this session, which then also closed TSG-25 (Tab. 4).

Tab. 4. List of papers and poster presented in Session 4

Paper and author(s)
[23] Impact of online automated learning path on student learning: the mindmath project in elementary algebra. ***Brigitte Grugeon-Allys****, Elann Lesnes-Cuisiniez and Fabrice Vandebrouck* (France). (SO)
[24] Engagement and moderation of mathematical modelling tasks in virtual environments. ***Joseph Simon Madrinan*** *and Catherine Vistro-Yu* (Philippines). (SO)
[25] Computer-dependent mathematics teaching in schools. *Rabindra Kumar Bhattacharyya* (India). (SO)
[26] Type of mathematics tasks with dynamic geometry software. ***Liping Yao*** (China). (SO)
[27] Strategic use of content-specific and content-neutral technologies to cater learning diversity in mathematics. ***Thomas K. F. Chiu*** (Hong Kong SAR, China). (SO)
[28] Digital tools and mediation in informal justification. ***Rikke Maagaard Gregersen*** (Denmark). (SO)
[29] Digital technology in relation to the mathematical thinking competency. ***Mathilde Kjaer Pedersen*** (Denmark), *Uffe Thomas Jankvist* (Afghanistan), *and Morten Misfeldt* (Denmark). (SO)
[30] Students mathematics experience of the technology self-directed learning (TSDL) pedagogy. ***Hoi Kei Melody Wong*** *and I. A. C. Mok* (Hong Kong SAR, China). (Poster)

3. Future Directions and Suggestions

The work in the TSG gives a good outset for continuation. Firstly, it became clear that we have a solid base of research on how technology is used in lower secondary mathematics. The work is most elaborated in relation to tools such as CAS and DGS where a shared language and some sort of paradigmatic organization. The language coming from the theory instrumental genesis has facilitated this positive development.

Apart from consolidating the concerns about CAS and DGS the TSG also showed the development of two new areas for mathematics education and technology in lower secondary teaching. The first of these areas can be described as embodiment, immersion and virtual/augmented reality. This area stood out as a promising future direction for mathematics education in the sense that augmented and virtual reality tools provide platforms for new mathematical experiences, and for the development of teaching materials. Lastly it was clear that computational thinking and programming is becoming very prominent in the curriculum and educational practices of mathematics teaching in various countries but is still under researched in mathematics education.

After the conference we had a survey-based evaluation of the work in TSG-25. Rather few participants answered the survey, but there was agreement that TSG was a good academic experience despite the online and hybrid format. There was also an interest in continuing collaboration and discussion on the topic. One participant asked for better possibilities for post conference publishing of the conference papers.