Introduction to the Thematic Working Group 18: International perspectives on mathematics teacher education and professional development: Current and emerging research

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In this paper, we review all of the contributions to TWG18, focusing on the range of research interests, theoretical perspectives and frameworks, and methodological approaches. From this review, the presentations, and discussions, the following future directions have emerged in relation to teacher education (TE): 1) Establishing and exploring research informed design principles; 2) summarising relevant theoretical directions; 3) exploring teacher change from an ethical perspective; and 4) scaling up innovative approaches within TE. In relation to professional development (PD), the following future directions have emerged: 1) Exploring the different roles of participants in PD; 2) exploring what makes change difficult and how professional growth best can be supported; and 3) understanding how we can best build on previous research, and each other, in order to develop the field of mathematics PD research.

Keywords: Educational research, mathematics teacher education, professional development.

Introduction.

Over recent decades, the study of mathematics teacher education (TE) and professional development (PD) has been a central focus of research. During previous ERME conferences, various research activities regarding these topics have been presented and discussed. Hošpesová et al. (2018) thematised the history of Thematic Working Group 18 (TWG18) and linked those topics addressed since CERME1 to questions related to theory and practice, collaborative environments, and reflection. In the CERME12 call for papers, TWG18 addressed a focus on research into prospective mathematics teachers' professional preparation as well as in-service teachers' professional development. The call invited discussions in relation to models and programs of PD as well as related practices (e.g., contents, methods, tools, and impacts). Within TWG18, 27 papers and 14 poster proposals were presented and discussed. Due to this large number of submissions, the TWG was divided into two sub-groups, specifically:

- TWG18a: **Mathematics Teacher Education** (TE) and Professional Development
- TWG18b: Mathematics Teacher Education and **Professional Development** (PD)

By offering a communicative, collegial, and critical forum for the discussion of these and other related issues, TWG18 attracts research from a diverse range of perspectives and theoretical approaches and contributes to the development of our knowledge and understanding as researchers, educators, and practitioners. TWG sessions 18a and 18b comprised both plenary and sub-group working phases. During the plenary phases, two or three papers and/or poster proposals were presented for a maximum of five minutes each, in which the authors highlighted their research interests, the main perspectives and frameworks (explicit, conceptual, theoretical, or practical), as well as the main methodological considerations in their research. These short presentations were followed by one or two discussants reacting to the research presented. Plenaries were followed by parallel sub-group discussions, which were each chaired by one of the discussants. Participants were able to choose and join a sub-group, where discussions lasted for approximately 20 minutes. All sub-group participants then came back together where central topics and issues were shared from each of the discussions. These central topics and issues, which came out of group discussions, often highlighted issues beyond the papers' scope and were recorded in the TWG's Padlet. Examples of issues beyond the papers' scope are ethical considerations in relation to teacher change and exploring how we can learn more about different participants' roles in PD. The content recorded in the Padlet was used when arranging specific topic discussions within TWG 18. The outcome, in form of emerging issues for the future, is described in the final section of this paper.

Building on Eisenhart (1991) and Lester (2005), this review of submissions to TWG18 is organised around three key aspects concerning the research process. The first aspect concerns the phenomenon of interest in the specific study, and how that research interest is justified, positioned, and explained. The second aspect is the choice of framework (theoretical, conceptual, or practical). According to Eisenhart (1991), theoretical perspectives include pre-defined concepts and assumptions that guide the research design. A *theoretical* framework uses a formal theory to establish explanations about a phenomenon. A *conceptual* framework can be viewed as a skeleton that justifies the study in relation to the aim (i.e., a set of assumptions about reality that underlies the research). A *practical* framework is guided by finding approaches that work in practice. Lester (2005) points out that the aim of research is not solely to select and use a conceptual framework, rather, researchers need to adjust and justify the conceptual framework in relation to their specific study. The final aspect concerning the research process is the set of methodological considerations concerning how to reduce the empirical material into meaningful data and how to present the results.

Based on this, this review paper will include sections aiming at answering the following questions:

- What were the **research interests** in the papers and poster proposals within TWG18?
- What were the main **perspectives and frameworks** in the papers and poster proposals?
- What were the main **methodological considerations** in the papers and poster proposals?

In addition to these three aspects, as explained above, we also summarise the emergent issues from the presentations and discussions within the groups, which we present towards the end of the paper.

Research interests.

A diverse range of research interests were presented within TWG18. Within TWG18a, research presented involved all phases of mathematics TE (primary, middle, and secondary phases). Most

commonly, research was focused on prospective mathematics teachers (PMTs) and their responses to: tasks and resources; hypothetical or real student(s); hypothetical or real interactions between teacher(s) and student(s); other prospective teachers; teacher educators; learning environments and tools. In TWG18b, many papers and poster proposals explored the design of research-based PD interventions as well as researching the different aspects of these interventions. The main aim of the PDs studied and presented in TWG18b can be summarised as collaboration between teachers or teachers and teacher educators or researchers in order to develop teaching practices, mainly towards more explorative approaches to teaching. In the PD research presented, the roles as facilitators, teachers, students (one or several) were explored.

Research interests: Teacher education.

Concerning the way PMTs respond to tasks and resources, *Sødal* researched PMTs' views in relation to the benefits of different aspects of working with resources in university coursework in preparing them for teaching mathematics. She found that working with resources can provide PMTs with practical and useful experiences as well as a way of combining content knowledge and core practices, to close the perceived gap between theory and practice. With regards to researching how PMTs respond to students' mathematics, *Henriques and Oliveira* researched the development of PMTs' knowledge in relation to students' mathematics reasoning. In this study, the PMTs' interpretations of students' mathematical reasoning processes were analysed and findings suggested that, over time, PMTs knowledge level improved. With a focus on the interactions between teachers and students, *Schnell and Fellenz* researched the role of 'Perspective Taking' in relation to PMTs' noticing students' mathematical thinking. In their study, they analysed the content of PMTs' written responses to a video clip of a mathematical interview. They found the most common perspective taken was one of task solver as opposed to teacher or student. Only two papers presented placed their focus upon the mathematics teacher educators (MTEs). *Longwe-Mandala and Fauskanger* explored ways in which MTEs in Malawi invite PMTs to participate during teacher education programmes, to better understand how these PMTs are enculturated into the practice of inviting learners to participate actively in lessons about number concepts and operations. *Ebbelind and Helliwell* explored the experiences of a group of primary PMTs during their teacher education programme in relation to the language-in-use of one MTE in Sweden.

Research interests also included ways to develop meaningful designs of mathematics teacher education programmes. Across the papers and poster proposals, researchers utilised well-established, as well as innovative pedagogical approaches within mathematics TE which, in some cases, became their focus of research. Examples of innovations include *Frejd et al's* use of a team-teaching approach called Socratic lectures to develop PMTs' communication skills and *Samková's* use of concept cartoons in primary teacher education to help assess prospective primary school teachers' knowledge on topics related to the primary school curriculum.

Research interests: Professional development.

As an example of research that explored the design of research-based PD interventions, *Grimeland et al.* investigated what kind of co-learning and learning gaps could be identified in a PD session on the topic of programming, a topic newly included in the Norwegian curriculum across grade levels.

Their findings indicate that both teachers and teacher educators learn about programming and lesson planning for programming during the PD. In addition, teacher educators learn about teachers' programming knowledge. One of the learning gaps identified is teacher educators' knowledge about use of programming in school.

Aiming at understanding how teachers reason about the role of high-quality mathematical tasks, a second example study analyses three groups of mathematics teachers engaged in collegial discussions as part of a national large-scale PD programme in Sweden. In this study, *Kaufmann* explores how the teachers reflect upon and explain the role of high-quality mathematical tasks when choosing tasks for use in their lessons. *Kaufmann*'s results indicate that the teachers appreciate high-quality tasks for providing student-to-student talk and for supporting students' collaborative efforts to solve problems. However, although these teachers appreciate high-quality tasks, they referred to such tasks as inappropriate for their students, blaming their students' capabilities, their lack of motivation to engage in such tasks, and their lack of experience with such tasks.

Problem solving was a focus of attention in several contributions. As an example, *Keller and Kohen* explore the learning processes occurring in online discussion forums as part of a 2-year PD programme where the teachers first acted as learners through collaborative solution of complex mathematical problems in small groups. Secondly, they led collaborative problem solving in forums as mentors. Based on exploring what is reflected in the teachers' pedagogical activities, *Keller and Kohen* conclude that problem solving forums have a high potential for developing teachers' own self-regulation skills, increasing their effectiveness in collaborative problem solving and empowering their support to students in solving complex mathematical problems.

In relation to exploring the roles of those participating in PD, one example is the study by *Skott and Ding* who focussed on the facilitator's role in lesson study by comparing how facilitators talk with teachers and what they focus their talk on. They use a framework consisting of mentoring strategies and content categories; both developed empirically in a Chinese and European context respectively. Their analysis showed big differences in the facilitators' ways of engaging in talk with teachers, including the dynamic and relational patterns in the Danish case as compared to the lengthy talk in the Chinese context. Based on their analysis, *Skott and Ding* argue that these differences are not only related to the fact that lesson study is new in Denmark, but also to social and cultural differences.

Perspectives and frameworks.

The studies shared within TWG18 were based on a wide variety of frameworks, depending on the research questions being answered and on the researchers' perspectives. In TWG18a different theoretical perspectives were used for the different facets of the teaching profession that the PMTs were prepared for. In TWG18b, different theoretical perspectives were used to guide the design of the PD programmes and also as underlying sets of concepts and ideas guiding the research design and the analysis.

Perspectives and frameworks: Teacher education.

Among the frameworks informing the facets of the teaching profession that the PMTs were prepared for, all three main objectives could be found in the papers and posters: knowledge, beliefs, and

practices, both individually and combined. From the perspective of Shulman's (1986) subject-matter knowledge (SMK) and pedagogical content knowledge (PCK), the majority of the papers and posters focused on PCK. In several cases (e.g., *Reitz-Koncebovski et al.*), SMK was connected to PCK via the model of school-related content knowledge (Dreher et al., 2018). The contributions studying PCK focused on one or more components of mathematical knowledge for teaching according to Ball et al. (2008) (e.g., *Schreiber*), on professional vision and noticing according to van Es and Sherin (2021) (e.g., *Karatsioli et al.*), or on diagnostic judgement according to Loibl et al. (2020) (e.g., *Schreiter et al.*). From the perspective of PMTs' beliefs and motivations, there were papers focusing on beliefs about resources for teaching mathematics (*Sødal*) or on motivation and communication skills (*Frejd et al.*). From the perspective of PMTs' practices, *Chikiwa and Graven* proceeded from the six-lens framework for guiding teachers' reflections on video-recorded lessons (Karsenty & Arcavi, 2017). One of the papers (*Karagoz Akar et al.*) focused on knowledge, beliefs, and practices all at once, and studied consistencies among them.

In TWG18a a wide range of different approaches to TE were introduced, including some recent or innovative approaches: for instance, transferring the concept of lesson study from PD to TE (*Ponte and Quaresma*), or transferring clinical simulations from the context of professional preparation of pilots, medical doctors, or nurses to the context of professional preparation of mathematics teachers (*Schreiber*).

Perspectives and frameworks: Professional development.

Among the frameworks informing the structure of the presented PD programmes, collaborative work between teachers is a common factor. The implementation of lesson study in new contexts was the focus of some studies including *Haringová and Medová* who studied the implementation of the lesson study approach in Slovakia. A further example of collaborative work in PD programmes can be found in the study by *Nurick et al.* where teachers participated in the VIDEO-LM project and discussed videotaped mathematics lessons using the "six-lens framework" (Karsenty & Arcavi, 2017).

There was a wide variety of approaches among the frameworks used to analyse research data and explain the phenomena behind them. The meta-didactical transposition framework (Chevallard, 1999) was used by *Pocalana et al.* as an interpretative lens to describe the interactions between teachers participating in PD and researchers acting as facilitators in the PD. In particular, they focused on the evolution of the praxeologies of both communities. In addition, *Pocalana et al.* used the boundary objects (BO) framework (Akkerman & Bakker, 2011) to explain the development of a shared praxeology between teachers and researchers, the internalisation processes of new elements for both communities, and the learning mechanisms activated by the design choices made by researchers for the PD program. Another study using the BO framework is the one by *Casi and Sabena* who interpreted museum collections to be BO connecting communities of students, teachers, and museum staff. As BOs, components of non-scientific museums acted as prompts for epistemological discussions about mathematics.

Collaboration among teachers has also been the focus of research analysis. *Keller and Kohen* studied the interactions of teachers in an online environment, where teachers participated in online forums. They analysed the participation of one teacher in the forum using the framework of collaborative

mathematics problem solving and its taxonomy of interactions (Clark et al., 2014), together with the components included in the Self-Regulated Learning framework (Boekaerts et al., 2000).

Methodological considerations.

Methodology can be understood as methods used for creating, gathering, or collecting empirical material and the specific reasons researchers have for using such techniques. As highlighted by Eisenhart (1991), this step also concerns how to reduce the empirical material into meaningful data worth highlighting in the result section. This section focuses therefore on the research design and sample size, methods for generating empirical material, structuring information, and generating data material for the results section in TWG18a and TWG18b.

Methodological considerations: Teacher education.

Research presented in TWG18a covered various research designs: qualitative, quantitative, and mixed methods research. Quantitative research included intervention studies involving a pre– and post– intervention test. For instance, the study by *Volkmer*. Other quantitative studies used written formats as data, such as *Dröse*, who used written diagnostic judgements from a group of PMTs (n = 26). These written judgements were coded with relation to knowledge elements for current or prior learning content using two dimensions of procedures and concepts. Quantitative studies consisted of up to 300 participants.

Half of all papers and posters related to TE were qualitative, covering single-case studies to those consisting of more than 50 participants. For example, *Samková* used indicative questions concerning a concept cartoon. The participants worked on tasks individually, and the data collected was processed using open coding and constant comparison to display subject-matter knowledge. *Ebbelind and Helliwell,* on the other hand, used a methodological tool to structure their empirical material from different contexts. Four contributions involved mixed methods. *Schreiter's* use of eye-tracking as a data collection method was a novel methodology within the TWG18a group.

Because of the various sample sizes and methods, the nature of the data is diverse. Methods for generating empirical material in TE research related to either: written reflections, answers to indicative questions, task solutions, lesson plans, questionnaires, recorded or transcribed interviews, video-recorded lessons, task analyses and movement tracking (mouse and eye). It is sometimes mentioned that theory sets standards for methodology, however, those researchers that use Loibl et al's (2020) diagnostic judgement use the full range of methods displayed within the TWG18a group.

Methodological considerations: Professional development.

Studies on teachers' PD in TWG18b included a systematic review of the literature on PD programmes and their relationship with student achievement (*Peri & Gomez Zaccarelli*) and a survey project on professional journals for mathematics teachers (*Asami-Johansson & Otaki*). The sample sizes in the presented studies ranged from two to 47 and up to several hundred participants: *Österling* conducted a visual and fine-grained analysis of two teachers' lessons in order to develop a framework for representing changes in mathematics teaching over time; *Keller and Kohen* explored the learning processes of 47 teachers when engaging in collaborative problem solving in online discussion forums. *Knaudt et al.* aim at developing adaptive training modules for in-service teachers at 125 primary

schools with the aim to foster teachers' diagnostic competences whilst considering the heterogeneity in the participants' individual learning prerequisites.

The majority of the presented studies in TWG18b used qualitative methods for investigating the participating teachers' professional growth: Data sources were videos from lessons (e.g., *Österling*), videos from PD sessions (*Nurick et al.*; *Haringová & Medová*) or interviews (e.g., *Neururer & Shúilleabháin*). In their comparative case study, for instance, *Koellner et al.* conducted semi-structured interviews using think aloud protocols for an in-depth investigation into teachers' practices five years after taking part in a PD programme. Many of the studies analysed written reflections or responses from teachers (e.g., *Keller & Kohen; Knaudt et al.*). *Kaufmann*, for example, analysed data on the reflections from teachers engaged in collegial discussion about the role of high-quality mathematical tasks. *Skott and Ding* investigated teachers' planning of lessons as data sources and explored potential changes. Only two studies (*Pocalana et al.; Knaudt et al.*) also made use of questionnaires: *Pocalana et al.*, for instance, administered a questionnaire to investigate teachers' praxeologies including teachers' beliefs about their students and about the teaching and learning of mathematics to complement qualitative data collected through interviews, written protocols, video recordings and reports about teachers' classroom experimentations. Looking across all studies addressing the professional growth of in-service teachers, various analytical frameworks were applied to analyse and structure the collected data: the commognitive framework (*Österling*); boundary objects theory (*Casi et al.; Pocalana et al.*); directed content analysis (*Keller & Kohen*); co-learning dimensions (*Grimeland et al.*), abductive process analysis (*Kaufmann*) or comparative case study analysis (*Koellner et al.*). Corresponding to the research focus of the respective studies, coding of participants' responses was, for instance, also based on levels of teacher noticing (*Fauskanger & Bjuland*) or stages of teachers' concern (*Neururer & Shúilleabháin*).

Emerging issues.

As highlighted in the introduction of this paper, group discussions often highlighted issues beyond the papers' scope. Therefore TWG18a and TWG18b arranged specific topic discussions during the conference. These issues were highlighted as emerging issues for the future and can serve as inspiration for forthcoming CERME conferences.

Issues from the discussions during TWG18a related to future TE research can be summarised as follows. Firstly, exploring whether it would be possible to establish a set of research based design principles for TE courses that would be applicable across different contexts, and what such principles might look like is a next step for TE research. To accomplish this, there is a need to share concrete task and course designs for TE programmes. Secondly, there is a need to summarise relevant theoretical directions in TE, to get a better sense of the different frameworks used within our community. A better understanding of different perspectives will not only strengthen our own research, but also contribute to more nuanced discussions in the future. Thirdly, teacher change was considered from an ethical perspective, with questions asked such as whether it is right to try to change teachers in certain ways, and who should make those decisions. Such ethical perspectives is in need for future explorations. Lastly, the question of how our research community might scale up innovative approaches should be explored.

Issues from the discussions during TWG18b related to future PD research can be summarised as follows. Firstly, future research should aim at exploring how we can learn more about different participants' roles in PD (i.e., students, teachers, teacher educators and researchers) whilst, at the same time, facilitate collaboration between all participants. Secondly, there is a need for exploring what makes change difficult and how professional growth best can be supported. Lastly, better understanding how we can build on previous research and each other in order to develop the field of mathematics PD research is an implication for future research.

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