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Introduction to the work of TWG09: Mathematics and language

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This paper is a summary of the work and discussions of Thematic Working Group (TWG) on Mathematics and Language. In this paper we provide an overview of both the presentations within the working group and of the main themes arising through the discussions. We highlight the diversity and richness of theoretical approaches, methodologies and research foci that lead to the rich discussions we have at CERME conferences. This richness also arose through a joint working session with TWG01 on argumentation and proof that brought different perspectives to the analysis of argumentation in interaction. We also consider the impact of the global pandemic on our data collection but also on the focus of our research within TWG09.

Keywords: Language, interaction, gestures, semiotics, written texts.

Introduction

The thematic working group 9 (TWG09) in CERME focuses on all aspects of language and mathematics, drawing on a diverse range of theories, methodologies and contexts. The importance of researching the role of language in mathematics is firmly established (Barwell et al., 2019; Erath et al., 2021; Morgan et al., 2021) and the working group contributions focus both on the mathematical content and the social, cultural or interactional context when researching the nature of this role. Over time the discussions of the working group have evolved and continue to evolve in line with developments in the field, and advance the work from previous ERME conferences. There is a great deal of richness and diversity in the range of methodological approaches, research foci, and contributions from the members of TWG09. This is partly as a consequence of the significant overlap the research included within the theme has with other working groups within the conference. Common connections include a focus on specific mathematical topics and practices such as multiplication, argumentation, or functions, as well as contexts of teacher professional development or mathematics teaching and learning in diverse and multilingual contexts.

Language is more than the medium through which the concepts and techniques of mathematics are taught and learnt, and this is widely illustrated in the work of TWG09. Research in this group is often characterised by the role that language can have in the learning of mathematics, in developing students' understanding of what it means to do mathematics, but also in terms of the barriers and obstacles it can raise for groups of learners. The research within TWG09 pays attention to how language, interaction and communication influences these processes of learning and teaching mathematics.

This diversity of perspectives, methodologies and connections both enriches the work of TWG09 but also poses a challenge for the group. This was already pointed out by Planas et al. (2019) with respect to the challenges related to presenting language-sensitive mathematics education research both during

a conference and in papers and posters. CERME12 saw changes to the template that have made it easier to share transcripts in a way that respects the language of the participants, respects the theoretical approach used by the researchers, and made members of this working group able to more effectively share their data. However, research within this group relies heavily on the analysis of interactions; interactions between teachers and students, interactions within groups of students, and interactions between students and tasks. The global pandemic has seen huge changes in the nature of these interactions with large scale school closures, a move to online synchronous and asynchronous forms of interaction, alongside greater concerns over privacy and data protection. These changes pose challenges to both the collection of interactional data and the presentation of data to illustrate findings from the work within this group.

The relevance of language in the various domains of mathematics education research has also been previously highlighted (Planas et al., 2019). During the 2022 conference, the methodological domains of descriptive and interpretive research for understanding teaching-learning processes in more detail, design research studies aiming at both theoretical insights and teaching-learning arrangements, and intervention studies were addressed. In TWG09 on mathematics and language, there is often a clear focus on qualitative studies with only Quabeck and Erath reporting from a larger-scale quantitative study and Kortüm et al. giving an outlook on planned quantitative research in their poster. Looking at the presented research at the conference from the perspective of the age of the participants, we gain insights moving across primary and secondary schools, across studies in Higher Education, towards studies with teachers with varying degrees of classroom experience. This shows how language and interaction matter for the learning of mathematics right from early years to the point of learning to teach mathematics that continues throughout a career. This diversity of perspectives and foci is illustrated through the keywords of the papers as illustrated in Table 1.

Table 1: Keywords from the papers and posters in TWG09

Language theories, constructs and approaches	Communication, Dialogism, Discourse analysis, Discourse, Gestures, Interaction (analysis), (Interactional) Quality, Language as resource, Language diversity, Language, Lexicalization, Linguistic complexity, Literacy, Participation, Register, Revoicing, Semiotic mediation, Semiotic representations, Social semiotics, Syntax, Teacher talk, Verbal tools,
General Theories, constructs and approaches	Abduction theory, Conceptual learning, Diagnostic, Epistemology/Epistemics, Images of mathematics, Interpretive research (paradigm), Learning opportunities, Literature reviews, Operationalization, Professional Identity, Professional knowing, Progression, Qualitative research, Responsiveness, Video study
Mathematical content	Argument/Argumentation, Combinatorics, Diagrammatic reasoning, Dynamic Geometry, Explanations, Generalisation, Geometry, Graphs, Inquiry-based/inquiry-oriented learning, Multiplication/multiplicative structures, Problem-solving, Reasoning, Time telling, Word problems, Writing

Contexts	Artifacts, Bilingual education, Classroom/teaching practice, CLIC, Educational television, Learning disabilities, Multilingualism/ Multilingual classrooms/ Multilingual teachers, Pandemic, Pluriliteracy, Primary school/elementary school, Prospective/preservice teachers, Reading, Teachers, Textbooks, Web-based/Digital tools
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The richness and diversity of research within TWG09 is not only visible in relation to contexts as well as the age and role of participants (see the Contexts in Table 1). It is also represented in the theoretical backgrounds of the presented studies as researchers drew from semiotic, dialogic, epistemological, pedagogic, sociological and interactionist perspectives (as shown in the range of theories, constructs and approaches in Table 1).and in some cases also connected different perspectives. These theories and approaches have also been used to focus on different aspects of mathematics, with many focusing on specific mathematical topics and others focusing on mathematical processes and skills.

Organisation of TWG09's work

The working group included presentations of 18 papers and 6 posters, with a total of 47 participants from 11 countries. The contributions are characterised by a strong and fruitful diversity in the contexts explored, research questions considered, and the theoretical and methodological approaches taken.

In the 7 sessions the papers and posters were discussed and organised around some common themes, although some of the papers could have been included in more than one of the identified themes. In organising the themes, we strived to enable connections and thus to foster possible future collaborations. Furthermore, as the groups' diversity can also be a challenge for discussing each paper in depth (Planas et al., 2019), the organisation around common themes was intended to help the audience focus and think deeply on one (maybe not so familiar) aspect of language and interaction in mathematics education.

In each of these 7 sessions, emphasis was placed on the time for discussion for each paper individually with depth. This was realised with a short 5 minutes to highlight the key features of a paper by authors followed by a 10-minute reaction focused on raising questions and generating discussions. The in-depth discussion of the individual papers within each session was made possible through the breakout discussions enabled by the technology. However, this also resulted in the group splitting into four smaller groups and each member of the group choosing which one paper to discuss with the authors in more depth.

Furthermore, one session was dedicated to discussing larger themes across the specific papers or posters for identifying new trends, common challenges, ideas for future collaborations, etc.

Contributions and themes

We first present a brief summary of each of the contributions presented in the TWG during the conference. The themes running through the contributions include the multimodality of language, topic-specific language demands including argumentation, interactional perspectives, written and

textual features of mathematics, and teacher education informed by language and mathematics research. We then conclude with some remarks on future challenges and directions highlighted during the discussions.

We opened with a paper from Huth that focused on the different functions of gestures in diagrammatic reasoning in primary school children's interactions. This was complemented with a poster presentation from Kimber and Smith on the relationship between speech and gestures in online teaching videos. Both these contributions focused on the different roles gestures can take in interaction in ways that both support mathematics learning, but also in ways that can constrain it. These different roles were also visible in the paper from Moutsios-Rentzos on multimodal argumentation in the joint session with TWG01 (Argumentation and Proof).

Several contributions from TWG09 focused on topic-specific language demands and semiotic representations that learners draw upon. Pacelli, Pellegrino, Carotenuto and Coppola reported on a project focusing on primary school learner's explanations when working with multiplication algorithms and the accompanying artefacts, presenting the specific case of Napier's bones. Also focusing on multiplicative reasoning in primary schools, Rønning distinguished between the multiplicative reasoning involved when working on different combinatorial problems that depended upon the semiotic representations used. The poster presentation by Şahin-Gür shifted the focus to calculus and learners aged 14 to 16 years by describing a design-research study to foster conceptual understanding in mathematical and language integrated learning-arrangements for qualitative calculus (i.e., understanding based on informal meanings of amount and change). Later contributions in the TWG sessions also included a focus on geometry in combination with digital technologies such as dynamic geometry software as discussed below.

The papers by Palm, Kapland and Bergvall and Planas focused on linguistic features and their role in the learning of mathematics. Palm et al. analysed how the changes in referents in textbooks for the final year in Swedish primary schools constructed opportunities for mathematical generalising. Planas drew on the notion of language as resource to argue for lexicalization as a potential resource for communicating mathematical meanings by reporting on her work with secondary school teachers. The papers in this session and the one that followed all focused on mathematics and language in interaction but in different ways. Bräuning and Feskorn focused on supporting interactional and communicative development of young learners in elementary school. Using an epistemological approach to the analysis of teacher-student interactions they illustrated how one teacher nurtured the students' development of mathematical interaction skills. Beck and Vogler continue this theme by examining responsiveness in interactions and the restrictions on primary school students' opportunities to participate resulting from particular teacher moves. Gíslason's focus on internally persuasive discourses also highlights the often restrictive nature of mathematical interaction, in that it often centres around visual or superficial features of a task rather than mathematical forms of argumentation and justification, this time arising from the students' interaction with dynamic geometry tasks.

Some contributions particularly focus on working with teachers with different levels of experience. Coppola, Ferrari and Miranda analysed student teachers' assessments of the written arguments made

by undergraduate students which revealed a lack of attention to argumentative structures and a focus instead on precise use of language and the mathematical content. The poster presentation of Perlander offered a different lens focusing on newly graduated teachers use of mathematical reasoning demonstrated in classroom interactions. In a later session, this focus on teachers and teacher education was continued in a poster presentation from Dafnopoulou who looked at how teachers' professional identities are developed in multilingual mathematics contexts.

Quabeck and Erath shifted the focus to look at how quantitative approaches have been used to capture the quality of mathematics classroom interaction. Their analysis reveals that only a focus on discourse practices, that many of the qualitative studies in TWG09 had, is sufficient to capture the relevant differences in classroom interaction rather than a focus on teacher moves or analysis at the task level that are commonly focused on in larger-scale studies. Ingram also examines differences in approaches to the analysis of classroom interactions, illustrating differences in the use of the term *revoicing* depending upon the theoretical perspective taken that have consequences on how we understand the relationship between teaching and learning of mathematics.

ETC7 on Language in the Mathematics Classroom already highlighted that the inclusion of digital learning environments and tools is an upcoming theme in the international research on language, interaction and learning mathematics (Ingram et al., 2020). In addition to the paper from Gíslason above, two other papers considered the role of digital technologies in the relationship between language and mathematics. Meaney and Rangnes focused on digital tools including programming and the importance of how teachers use them with multilingual learners. They made a distinction between tools that acted as translators and tools that were used more broadly and consequently were more supportive in developing multilingual learners' mathematics and their language in mathematics. Baschek explored the use of *PrimarWebQuests* in Content- and Language-Integrated Learning (CLIL) settings in primary school illustrating the motivation of authentic contexts for students to use different working languages and offering an illustration of one such context in the webquests. This focus on CLIL was continued in the paper by Schüler-Meyer who suggested the notion of pluriliteracy as an alternative in CLIL with a shift in emphasis on learners becoming proficient in mathematics using multiple languages, rather than the common target language in focus in the CLIL settings.

In the final session the focus shifted to written mathematics continuing the development of this work across several ERME conferences. Malik and Rezat's paper focused on identifying specific linguistic features that cause learners difficulties in word problems by presenting a literature review. Teledahl, Ahl, Helenius and Kilhamn also analysed several research frameworks for assessing students' writing and illustrated by their literature review that further research is needed to develop research that attends to the different dimensions of students' writing. Kortüm, Meininghaus, Mentrop, Hußmann A., Hußmann St. and Nührenbörger also shared their work on developing a supportive diagnostic tool to assess reading and mathematical competencies and their interconnections. The TWG09 sessions ended with a final presentation from Tatsis and Maj-Tatsis that focused on the public discourses around educational television programs in Poland during the pandemic.

Argumentation and a joint session with TWG01

There was a joint session between TWG09 and TWG01 to bring together the overlapping focus of argumentation that often features in the papers of TWG09. During the virtual pre-CERME12 event, members of TWG09 discussed the idea of a joint session with another TWG at CERME12 as well as which other TWGs to approach. In this way, the members of TWG09 wanted to further embrace the CERME spirit and promote communication, cooperation and collaboration. Fortunately, the leaders and members of TWG01 on Argumentation and Proof were as enthusiastic about this idea as TWG09. Even though, there was always exchange between different TWGs, we are proud to be part of the first official joint session in CERME history and hope that there will be many more at upcoming conferences.

The joint session included two papers from TWG01 focusing on theoretical debates around the conceptualisation of argumentations and two papers from TWG09 focusing on examples of argumentation in practice. The paper of Moutsios-Rentzos began by challenging us to consider the multimodal aspects of argumentation and offering a tool to support the identification of specific ways in which verbal and non-verbal semiotic systems are both explicitly and implicitly used in mathematical argumentation. This paper drew on Toulmin's scheme of argumentation which is widely used by researchers in both working groups. In the next paper Cramer and Kempen challenged the extent to which this scheme can reveal all aspects of structures of argumentation, highlighting the limitations of the scheme as revealed through recent work within TWG01. The two papers from TWG09 focused on discourses of argumentation with Körner and Meyer illustrating the generalising process over time focusing on addition with zero and tracing one learner's development of argumentation during an interview. Toro and Castro then shifted our focus to mathematics teachers' argumentation during class discussions and how features and purposes of argumentation can be recognised through an interactional and communicative theoretical perspective.

The joint discussion in this session highlighted the different theoretical perspectives and approaches to the analysis of mathematical argumentation, and the nature of mathematical argumentation itself, yet with a common focus on identifying and recognising features of argumentation used by both teachers and learners.

Themes and challenges going forward

One session during the conference was organised without the presentation and discussion of particular contributions. Instead, it was organised as a collaborative working session with a focus on identifying and discussing themes and challenges going forward. The group members split in three smaller groups to focus on 1) how different theoretical perspectives can complement each other, 2) research issues challenging the field at the moment, and 3) implications for the professional development of mathematics teachers.

Over several CERMEs and ERME topic conferences there has been continuing focus on the use of different theoretical perspectives to research mathematics and language (e.g. Planas et al., 2019; Ingram et al., 2021). This is partly as a consequence of the range of fields research in mathematics and language draws from but also theoretical diversity is needed to address the complexity of the relationship between mathematics and language, particularly in the messiness of interactions.

Susanne Prediger illustrated this in her plenary presentation where she illustrated the range of theoretical perspectives and methodologies she has used in her work over a research agenda across several years (Prediger, 2022). Furthermore, as discussed in the joint session, since mathematics communication includes writing, talking, pictures, formulas, gestures, we need more refined theoretical tools than existing models (such as Toulmin's model) to capture its nature.

As already indicated at the beginning, one research issue challenging the field at the moment is that many researchers were not able to collect new data of language use and interaction in classrooms or even of small groups in schools due to school closures and restrictions. For researchers whose analysis often depend on video-taped interaction or who are interested in data from the same classroom in a more longitudinal perspective, this poses a huge challenge. Whereas more senior researchers may go back to “old but still rich” data, early career researchers and researchers starting new projects particularly struggle. In this context, it was also reported from different contexts, that (as schools are more and more challenged by the pandemic and other factors) access to schools becomes increasingly difficult, particularly in contexts in which, for example, teachers cannot be rewarded for their participation in research efforts. A third discussed point is that after a period of some political awareness for language and learning mathematics, other aspects are highlighted (as for example distance learning or digital tools) and more and more funding is directed towards subfields of mathematics education research without explicit connection to language and interaction.

The topic of teacher education has become particularly prominent in several recent CERMEs and topic conferences (e.g. Planas et al., 2019; Ingram et al., 2021), and is growing in importance as a focus of much of the research within this working group. Many of the participants are teacher educators and recognise the complexity of supporting teachers to recognise, identify and adopt linguistic features, teacher moves or interactional practices that support mathematics learning. Furthermore, it can be noticed that some projects on the classroom level reported in earlier conferences are now developed into a basis for the design of professional development programs focusing on language, interaction and learning mathematics.

Concluding remarks

The themes addressed by TWG09 show the variety of research questions, theoretical perspectives and methodologies that the papers and posters dealt with. Whilst this conference maintained this richness in the research and data shared, we have shifts in the focus of the research included. This may be a consequence of the nature of data it has been possible to collect and work on during the global pandemic, with fewer studies focusing on interactions within classrooms. In addition, there might be a general increase of attention to digital communication settings. It may also illustrate the interactions and connections with other working groups where many members welcome discussions that result from connections with these other groups. The joint session with TWG01 highlights how connections between working groups can add to this richness by offering different perspectives at the intersections of our research.

Acknowledgment

We want to thank all the participants of TWG09 who contributed through presentations and thoughtful discussions. We would also like to thank the participants of TWG01 who contributed to

the joint session leading to fruitful discussions around conceptualisations and illustrations of argumentation that cut across the two working groups. A special thanks goes to Alexander Schüler-Meyer who supported us during the conference and Aurélie Chesnais who supported as in the preparation of the conference.

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