# PME NEWSLETTER 2026






PME49 HELSINKI

Reflecting on 2026

PME50 TOKYO

Looking ahead to 2027

International Group for the Psychology of Mathematics Education

INTERNATIONAL GROUP FOR THE PSYCHOLOGY OF MATHEMATICS EDUCATION

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INTERNATIONAL GROUP FOR THE PSYCHOLOGY OF MATHEMATICS EDUCATION

## Message from the President

Oh Nam Kwon | PME President

Dear members of PME,

Looking back on PME49 in Helsinki, I am grateful to everyone who contributed to our gathering. With 789 participants from 51 countries and 648 contributions, the conference brought together a remarkable range of perspectives and reminded us of the strength of our international community.

My warm thanks go to the conference co-chairs, Markku S. Hannula and Heidi Krzywacki, the Local Organizing Committee, and everyone who supported the conference. The collaboration among colleagues from universities across Finland made this gathering possible. I also thank the University of Helsinki, the City of Helsinki, and the Federation of Finnish Learned Societies for their hospitality and support.

The theme, "Sensing and making sense of mathematics," invited us to consider how our bodies, senses, and interactions shape mathematical learning. Across plenary sessions, research presentations, and working groups, we had opportunities to question familiar assumptions and learn from one another. The working-group reports in this newsletter offer a way to continue those conversations beyond Helsinki.

For me, PME remains a professional and intellectual home: a place where we share research, develop ideas, and build relationships through openness and care. Thank you to every participant who contributed to that spirit, whether by presenting, asking a question, supporting a colleague, or opening a new conversation.

As we look towards PME50 in Tokyo, Japan (19–24 July 2027), I hope we will carry this spirit forward. Our preconference webinars provide another opportunity to connect, particularly for colleagues beginning their PME journey. Supporting participation and creating space for early-career researchers remain central to the community we want to sustain.

I invite you to stay involved, continue the collaborations begun in Helsinki, and help shape PME's next chapter.

With warm wishes,

Oh Nam Kwon

Oh Nam Kwon
President of IGPME
Seoul National University, South Korea

# PME49 working group reports

Reports from the working groups continue the conversations begun in Helsinki. The following pages include the submitted reports.

## EARLY MENTAL MATHEMATICS INTERVENTION MODELS AND DATA IN LOW ATTAINMENT CONTEXTS

Authors: Hamsa Venkatakrishnan; Mellony Graven; Lawan Abdulhamid; Justina Longwe; Angel Mukuka; Tandeep Kaur; Mike Askew

The Early Mental Mathematics Working Group focused on sharing and discussing different models of intervention and different datasets being collected across projects supporting the development of flexible and efficient mental mathematics. While initially, the aim was to separate the sessions based on intervention models and data sources/data analysis, we decided, based on the contributions to demarcate the two sessions according to pre-service and in-service interventions. In this report, we summarise the session inputs and the discussions that ensued in the Working Group. In both sessions, there were approximately 20 participants.

The background to the Working Group's focus was the evidence that early mental mathematics both underpins, and bolsters, the number sense that builds strong foundations for mathematical learning (Chu et al, 2018). However, in many parts of the world, most children fail to meet even core grade level outcomes in mathematics at early primary level (UNICEF, 2022), with 'learning poverty' particularly marked in sub-Saharan Africa.

The presentations in the Working Group were linked to materials developed within the Mental Starters Assessment Project (MSAP) in South Africa (Graven et al, 2025). In earlier trials linked to this project, promising outcomes had been reported at in- and pre-service projects of increasing scale (Graven & Venkat, 2021; Askew et al, 2022). The Working Group was unusual in terms of its Africa-centric locus of examples of intervention studies and data collations, attending to concerns that have a broader international reach as attested to in the multi-continental composition of the audience drawn from Australasia, Europe and the Americas. Respondent Mike Askew raised questions from broader international perspectives on the presentations in Session 1, and orchestrated discussions following his inputs.

**Session 1: Early number interventions models, materials and data at in-service level**

This session began with brief inputs from projects in South Africa (Hamsa Venkat, Mellony Graven & Tandeep Kaur), Nigeria (Lawan Abdulhamid & Balarabe Yushau) and Zambia (Angel Mukuka). These interventions are working with different units within the MSAP materials, but all work with a blended attention to the materials' focus on developing mental mathematics 'fluencies' and 'strategies'. However, the projects differed widely in their scale and in their data sources and analyses. Discussions in this session focused on the relationship between fluencies and strategies—a common focus across the data presented (with higher gains on fluencies reported in the South African and Zambian data excerpts presented). There was also comment on what the quantitative analysis of larger-scale intervention in South Africa allowed and what remained obscured in that project's dataset.

There was widespread interest in the materials with their open-source availability allowing for sharing after the session, and strong agreement that the distinction between inefficient one-by-one counting-based approaches and efficient strategic calculation was important in many contexts.

### Session 2: Early number interventions models, materials and data at pre-service level

This session included inputs from South Africa (Tarryn Lovemore, Tammy Booysens & Corin Mathews), Malawi (Mercy Kazima) and Nigeria (Lawan Abdulhamid & Balarabe Yushau). In South Africa and Nigeria, projects involved multiple institutions on the ground, again working with the MSAP materials, which, since 2022, have been part of nationally advocated rollout.

Across the institutional groups working on pre-service projects, the audience noted ways in which the smaller scale allowed for qualitative data gathering that provided insights into how representations, gestures and explanations were being developed as part of pre-service teachers' repertoires.

In the Working Group discussions, questions were asked about the context and conditions of initial teacher education that had both necessitated and facilitated inclusion of attention to mental mathematics. There was, once again, affirmation that the issue of poor number sense leading to inefficient and/or rote algorithmic work, was widely recognised.

### Plans for further work

Small-group feedback indicated broad interest in interventions and data analysis linked to improving early number sense and mental mathematics. The presence of editors of the upcoming Special Issues of the Mathematics Education Research Journal on early number sense and the African Journal for Research in Mathematics, Science and Technology Education on early number calculation was significant for the Working Group team, providing visibility for a range of African studies in the broader international field. Immediate follow-up work is focused on developing articles for submission to these Special Issues. Longer-term work will explore further avenues for building cross-continental collaboration on mental mathematics and its development in the early grades of schooling.

### Acknowledgements

This work is supported by funding from the European Commission under the Regional Teachers Initiative for Africa.

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# PROCEDURAL FLEXIBILITY: DEFINING, ASSESSING, AND DISCUSSING CURRENT DIRECTIONS IN FLEXIBILITY

Authors: Christoph Ableitinger; Christian Dorner; Peter Hästö; Alina Kadluba

The PME49 working group on procedural flexibility grew from an international network that meets informally to discuss how scholars in the field conceptualize and measure procedural flexibility. Our shared aim in Helsinki was to surface different approaches, find productive common ground, and sketch practical next steps for the field. We anchored our conversations in Star and Newton's (2009) two-component view of flexibility: knowing multiple strategies and selecting the most appropriate one. At the same time, we kept different approaches to measuring procedural flexibility in focus. Existing instruments, especially Xu et al. (2017), offer a strong starting point but leave open questions about test length, content coverage beyond linear equations, and the role of task characteristics.

Session 1: We opened by presenting different terminologies researchers use in their work on procedural flexibility. In small groups, participants compared definitions of procedural flexibility and related constructs. Using the Star and Newton (2009) lens, groups discussed how different terminologies have proven effective across mathematical content areas and learning contexts. A closing plenary identified points of agreement, documented disagreements worth pursuing, and aspects requiring further refinement.

Session 2: The second session shifted from terminology to measurement. Following a brief overview of the tri-phase assessment by Xu et al. (2017), participants analyzed student data related to procedural tasks provided by the organizers. Groups pursued two goals: first, to trace students' justifications, e.g. why particular strategies were chosen for particular test items; second, to examine how task characteristics influenced strategy choice. Both lines of inquiry feed into the design of test instruments for procedural flexibility.

Our work yielded several takeaways. First, there are at least two 'worlds' of flexibility in mathematics education. For routine problems, flexibility depends on the knowledge of multiple successful strategies and selecting well among them. For non-routine problems, the ability to shift strategies, even after an unsuccessful attempt, is pivotal. Second, the group did not view strict standardization of terminology as a priority. Fixed conceptualizations may be counterproductive across mathematical domains, languages and traditions. Instead, authors should define their terms explicitly in each paper, remain alert to jingle–jangle fallacies, and clarify links to neighboring constructs. Still, within a given paradigm (e.g., deep procedural knowledge), consistent usage is desirable to enable comparison and accumulation of findings. Third, content matters. Flexibility can look different across domains: some topics offer only a few strategies (certain linear equations), whereas others invite many (fraction comparison, area problems).

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# SENSE-MAKING IN EXTENDED REALITY: EXPLORING EMBODIED MATHEMATICAL INTERACTIONS USING SMART DEVICES AND HEAD-MOUNTED DISPLAYS

Authors: Daniel Vadim O'Brien; Katherine Riding; Michael Rumbelow; Korbinian Moeller; Colin Foster

## OVERVIEW

Working Group 11 addressed the PME-49 conference theme of "Sensing and Making Sense of Mathematics" by examining how sensory, gestural and spatial interaction shape embodied mathematical sense-making across handheld and head-mounted Extended Reality (XR). Through hands-on engagement across three activities, co-participants collaboratively analyzed the affordances and constraints of handheld and HMD-based XR; identified practical design, classroom and methodological considerations; and suggested future research directions. Each activity station was equipped with HMDs and smart devices (see **Figure 1**).

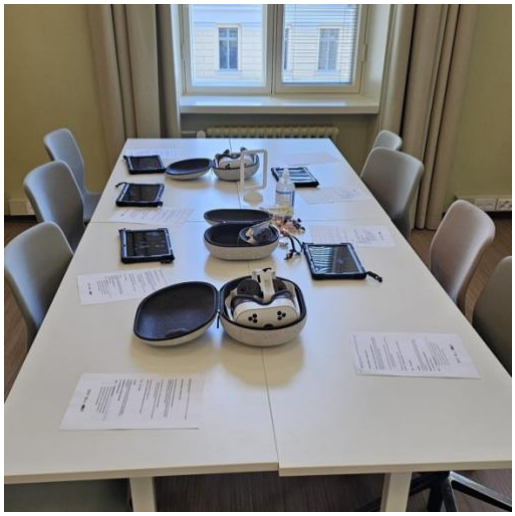


***Figure 1:*** *Activity Station with HMDs and tablets*

## PARTICIPATION AND APPROACH

The working group attracted 13 participants, affiliated with a range of institutions across eight countries: China, Finland, Germany, Israel, Italy, Taiwan, Turkey and the UK. Participants were invited to review an information sheet and complete a paper consent form if they wished to opt into anonymized data collection. The results summarized here comprise task sheet comments, facilitated discussion and feedback from an in-session *Mentimeter* poll.

## STRUCTURE AND ACTIVITIES

### First WG Session, 28th July 2026

The first session began with a presentation of the XR Continuum, the development of AR in mathematics education and health and safety guidance regarding the hardware. Participants formed three groups across three tables and completed two 30-minute stations. One question guided attention: *How do the different XR technologies influence what you notice, how you move, and how you reason about the mathematical structure?*

***Table 1: Workshop stations***

| Activity Station | XR configuration | Task overview |
|---|---|---|
| **Fractions in AR** | ***FractAR* on HMD and *GeoGebra* 3D/AR on a tablet** | Walk through a set of pre-loaded audiovisual UI training exercises, an animation and tasks to construct, compare and, as an extension activity, add fractions – using a novel spiral "magic staircase" design: www.bit.ly/WG11AS2 |
| **Plans and elevations in AR** | *Cubism* on an HMD and *GeoGebra 3D/AR* on a smartphone | Construct 3D structures from a mathematics examination "Plans and Elevations" question for middle school students. Compare construction process on *Cubism* (HMD) and *GeoGebra 3D/AR* (handheld): www.bit.ly/WG11AS1 |
| **DIY XR** | ***Polycam*, *youtube360*, *Google Cardboard* and generative AI** | Create and explore low-cost XR by scanning objects into manipulable 3D models, viewing 360° videos through *Google Cardboard* and prompting generative AI to produce immersive environments for mathematics education: www.bit.ly/WG11AS3 |

**Second WG Session, 30th July 2026**

Groups completed their remaining station during the first 30 minutes. A short *Mentimeter* poll and whole-group discussion then compared enjoyment, perceived support for mathematical sense-making, movement in 3D space, classroom feasibility and research priorities. The final 30 minutes allowed participants to explore further HMD and handheld XR applications.

## OUTCOMES AND REFLECTIONS

### Activity 1: Plans and elevations in AR

*Cubism* supported direct construction and understanding of 3D structures but raised usability, accessibility and isolation concerns, while *GeoGebra* enabled rotation, verification and easier sharing but could feel less intuitive and constrained by phone screens. Both showed potential for spatial reasoning and learning about plans and elevations, although participants' views on potential for collaboration were mixed and they questioned XR's added value over physical cubes.

### Activity 2: Fractions in AR (*"FractAR"*)

Feedback highlighted *FractAR*'s potential to support engaging, embodied exploration of fractions. Participants examined how a 3D "magic spiral staircase" connected the pizza and number-line representations (see **Figure 2**). They valued its potential for motivation and embodied engagement but also noted that it required familiarization with the controls and presented practical classroom challenges. The handheld version rendered in *GeoGebra 3D/AR* was generally found to offer more intuitive, shareable interaction better suited to collaboration but found it more limited and artificial.

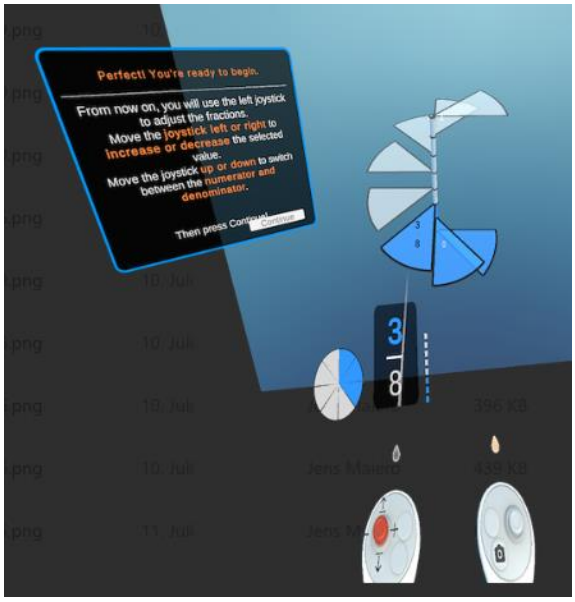



***Figure 2**: user's view of FractAR (without background)*

### Activity 3: DIY XR

Participants identified potential uses for DIY XR in visualising and exploring 3D geometry, with low-cost tools offering accessible immersive experiences but presenting significant device-compatibility constraints. Outputs included rotatable 3D scans demonstrating symmetry and participant-prompted AI-generated 360° environments (e.g. see **Figure 3**), while discussion highlighted applications to geometry problems, polyhedra and spatial relationships.

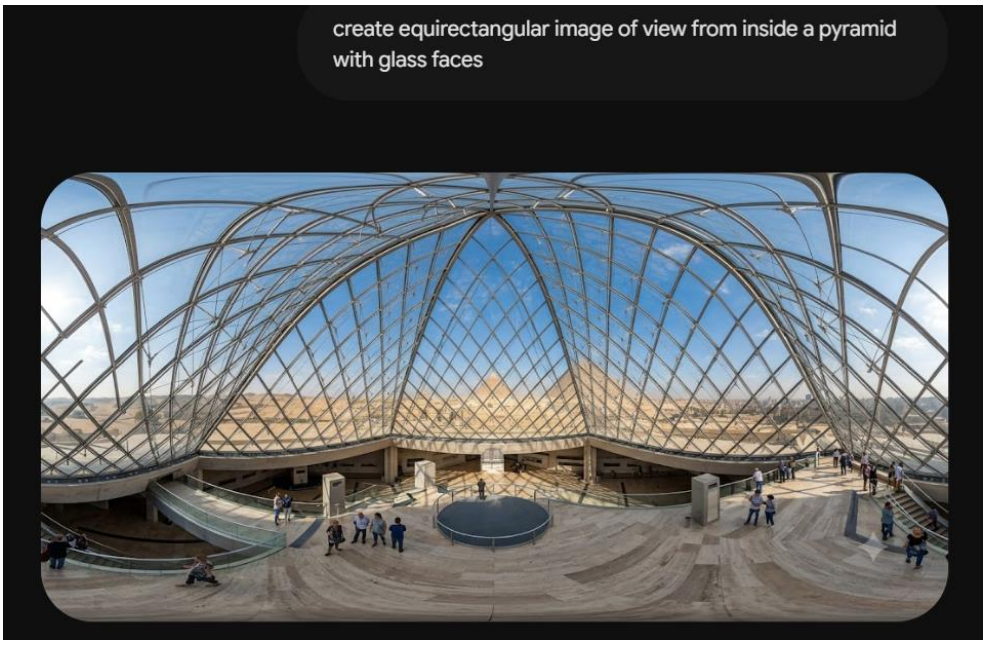



***Figure 3:** an equirectangular image created by Gemini via a participant's suggested prompt*

### Feedback from summary poll

Up to 13 participants responded to the final *Mentimeter* poll – see **Figure 4**.

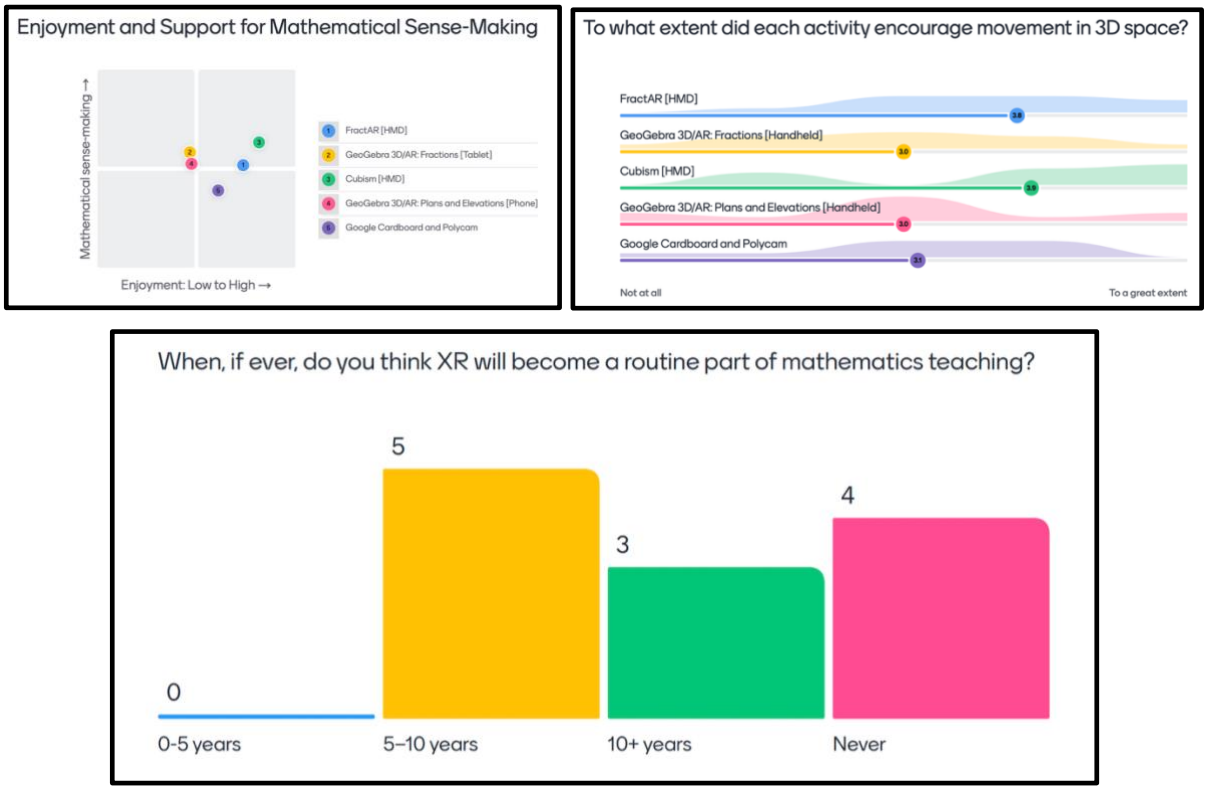



***Figure 4:*** *Mentimeter ratings*

Overall, participants valued the immersion, tangibility and movement afforded by XR, but enjoyment did not necessarily correspond to perceived mathematical support and technological interaction could sometimes compete with mathematical attention. HMDs offered greater immersion but presented challenges for collaboration, comfort and accessibility, whereas handheld devices better supported shared attention but had their own interaction constraints. Overall, no interface was preferable for every purpose: the findings suggest that mathematical value depends on how well the task, software, interface and classroom arrangement are aligned.

### Future Research Directions

Triangulating future research questions suggested by the participants with the activity outcomes, we thus identified four priorities for future research:

- **Investigate how bodily action, gaze, gesture, speech and representations support mathematical meaning-making across interfaces;**
- **Compare spatial and conceptual learning across hardware conditions using functionally and visually matched mathematical tasks and software environments.**
- **Develop collaborative roles and teacher-monitoring strategies for immersive classrooms;**
- **Examine access, comfort, prior experience and device compatibility, including differences between directed activity and free or learner-generated exploration.**

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# MATHEMATICAL-PEDAGOGICAL (MP) TASKS IN TEACHER EDUCATION: DESIGN, TEACHING AND RESEARCH

Authors: Ami Maria Mamolo; Rina Zazkis

In this Working Group, we aimed to explore the use and potential growth of teachers' mathematical knowledge via pedagogical engagement. We introduced the construct of a *mathematical-pedagogical task* (in what follows, *MP Task*), defined as a task in teacher education that uses a pedagogical setting to explore and strengthen teachers' knowledge of underlying mathematical ideas. The **goals** of this WG were to: (1) Introduce the idea of MP Task as a research and instructional tool in mathematics teacher education; (2) Explore various interpretations and diverse uses of MP Tasks; and (3) Design and mobilize new MP tasks and new collaborations. The main feature of this WG was to engage with tasks.

The first session began with a metaphor and demonstration: *when exercising, if you are asked to 'touch your toes without bending your knees', the goal is not really to touch toes - it is to stretch your muscles .* With this metaphor in mind, we examined a variety of MP tasks in which teachers are invited to respond to a pedagogical situation, where the goal is to strengthen mathematics. As an illustration, consider the dialogue below, in which teachers were asked to respond to a student's question, as presented in Zazkis and Kontorovich (2016):

Student: 3 to the negative 1 is one third [writes $3^{-1} = \frac{1}{3}$], right?

Rachel: Right.

Student: So power 'minus 1' means reciprocal, right?

Rachel: Right.

Student: But f-to-minus-1 [writes $f^{-1}$] means the inverse function, this does not mean 1/f, right?

Rachel: Right.

Student: So they ran out of symbols, or what?

In order to respond pedagogically (touch your toes), one must engage mathematically (stretch your muscles ). We examined a diverse set of MP tasks with an eye toward the underlying mathematical ideas and discussed personal and collective goals for strengthening teachers' understanding of these ideas. Presentations by Ofer Marmur (University of Auckland), Jérôme Proulx (King's College), and Boris Koichu (Weizmann Institute of Science) highlighted ways that research can inform the design and implementation of MP tasks. Among the ideas explored, WG participants analysed MP tasks related to unpacking a student's problematic solution to finding an inverse function by switching variable (Alvarez, et al., 2020), comparing the explanatory power of different representations of the relationship between slopes of perpendicular lines (Mamolo & Zazkis, 2026), and addressing a student's claim that fractions can take different forms for the same number while decimals are always unique (Serbin & Bae, 2025).

WG participants discussed and shared their personal and collective goals for strengthening teachers' mathematics for teaching, including:

- Flexibility in content, practices, and explanations
- Problem solving and problem posing
- Well-being, confidence, and efficacy
- Ability to cope with uncertainty, resilience
- 'Big ideas', mathematical structure, and conceptual understanding

- Links between secondary and tertiary mathematics

The second session began with an exploration of two mathematics tasks, the well-known handshake problem, as well as a combinatorial problem related to constructing trains (McKie, et al., 2025). This exploration led to a rich discussion regarding how to develop 'M' tasks into 'MP' tasks according to the personal and collective goals of WG participants. To this end, WG participants discussed several strategies, coordinating and co-developing ideas via a collaborative web-based document. Key themes and questions that emerged from this discussion included:

- How do MTEs work with tasks in order to surface their intended mathematics goals?
- Is there a need for MTEs to "know the answer" before using a mathematics task in class or before adapting a mathematics task into an MP task? (Answer: it depends)
- Is a MP task a 'ruse' or backdoor to mathematics? (Answer: it is not a ruse, it is a realistic context that teachers will experience)
- Strengthening mathematics depends on the prior knowledge of the teacher, so how to predict what mathematics needs to be strengthened?
- What is the delicate balance of 'pushing' in a particular (mathematical) direction and being open / inclusive of potential (pedagogical) directions teachers bring to the discussion?
- The familiar invitation to "solve" a mathematics problem can create anxiety for teachers and shift attention away from the intended learning of the task. Alternative phrasings were suggested, such as:
- Asking teachers to simplify a task for students, scaffold it, or extend it;
- Creating isomorphic tasks, with similar solutions and different contexts;
- Purposefully selecting different student solutions and inviting teachers to compare and contrast;
- Inviting teachers to anticipate where students might get stuck on a particular mathematics task, and why so.

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# SENSING AND MAKING SENSE OF DEVELOPING SUSTAINABLE RESEARCH PRACTICE PARTNERSHIPS

Authors: Limin Jao; Richelle Marynowski

Research-practice partnerships (RPPs) offer opportunities for researchers and practitioners to work together over time to address problems emerging from practice, while drawing on the knowledge and expertise of all partners. This Working Group explored the challenges and possibilities of developing and sustaining such partnerships across diverse educational contexts. The first session focused on participants' experiences of developing, or attempting to develop, RPPs, while the second session built on these experiences to consider possible strategies and future directions for more sustainable partnerships.

In the first session, participants shared experiences of partnerships in different educational and institutional contexts. Several recurring tensions emerged. Building trust and establishing relationships were seen as essential, particularly given concerns about teachers feeling evaluated by researchers and the power dynamics that can arise when researchers initially connect with school administrators rather than teachers. Participants also questioned what it means for a partnership to be "symmetrical" and/or "complementary", and whose voices and expertise are represented in research outputs. Questions of whose "problem of practice" is being addressed, who initiates and negotiates the research agenda, and who has the authority to sustain or dissolve a partnership highlighted the importance of attending to power throughout the life of an RPP. Time, funding, and institutional structures were also identified as persistent challenges. Participants noted that teachers may have limited time to participate in research, while research and funding cycles do not necessarily align with school schedules. Differences between researchers' and teachers' goals, as well as tensions between professional learning and research purposes, can further complicate partnerships. At the same time, participants identified enabling conditions, including: clear and regular communication, mutual benefits, teachers' interest in examining their own practice, structural support for research in schools, and opportunities for reciprocal engagement.

The second session shifted from examining challenges to considering how sustainable RPPs might be developed. A plausible scenario involving a school district and university research team was used to generate discussion. Participants emphasized the importance of involving teachers early in conversations about problems of practice and finding a zone of alignment between teachers' interests and researchers' questions. Negotiation, flexibility, compromise, and ongoing investment from all partners were considered important to partnership development. Participants also discussed the importance of moving beyond extractive research relationships toward forms of co-learning in which researchers contribute to teachers' practice and leave resources, structures, or reflective practices that can continue after a research project ends.

In the final reflections, participants noted that learning from others' experiences can make visible assumptions about how RPPs develop and open up alternative ways of working. An approach that engages teachers as active participants in research and considers what researchers can contribute to teachers and schools was seen as a promising way forward. Participants also expressed interest in continuing to learn across national and cultural contexts, particularly in relation to teacher professional learning and research. Possible future directions included developing case studies using a common set of prompts or framework to facilitate comparisons across partnerships, as well as exploring opportunities for international and cross-cultural collaboration. The Working Group concluded with a shared interest in continuing to examine how RPPs evolve across contexts and how researchers and practitioners can build partnerships that are reciprocal, responsive, and sustainable. The Working Group welcomes additional collaborators. Please reach out to the group's contact person (in bold).

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# MAKING SENSE OF HIGH-QUALITY MATHEMATICS INSTRUCTION ACROSS CULTURES: TOWARDS A MORE INCLUSIVE CHARACTERISATION

Authors: Ban Heng Choy; Michal Ayalon; Arindam Bose; Ceneida Fernández

### Overview of the Working Group Activities

Although effective mathematics teaching can take many forms, debate continues about which characteristics define high-quality mathematics instruction and how these characteristics vary across cultural and educational contexts. The working group therefore aimed to examine different dimensions of effective teaching and develop a more inclusive characterisation of high-quality mathematics instruction. Two questions framed the activities and discussions:

- What are the similarities, differences, and tensions in our characterisations of high-quality mathematics instruction practised across the globe?
- What potential refinements or extensions to the existing dimensions of high-quality mathematics instruction could acknowledge and draw from the diversity of effective teaching practices across different parts of the world?

We began the first session by setting the context and sharing the key questions this working group will explore. We elicited participants' responses (n = 25) on their current characterisation of high-quality mathematics instruction and summarised these ideas on a word cloud (see Figure 1).

*Figure 1: Word Cloud generated by participants of the Working Group*




Session 1 addressed the first question through two contrasting videos of mathematics instruction, one from the USA and the other from India. After receiving contextual information and accompanying materials where available, participants discussed the lessons in groups to identify similarities, differences and tensions in applying existing frameworks. A whole-group discussion then consolidated the emerging insights and identified focal issues for Session 2. After recapping these issues, Session 2 focused on the second question. Participants worked in small groups to explore possible refinements, extensions or reframings of selected dimensions in light of the tensions identified earlier. They then watched a video of a Japanese mathematics lesson and concluded by mapping key tensions and exploratory directions for future collaboration.

## Key Ideas from the Sessions

The discussions generated three connected insights: participants identified broad common ground on the qualities of effective instruction, examined tensions in how those qualities are enacted and interpreted across contexts, and proposed refinements to how HQMI is characterised. Overall, participants examined how high-quality mathematics instruction (HQMI) might be characterised across diverse educational and cultural contexts. Their discussions revealed both convergence and variation: they identified several broad characteristics of quality while recognising that the enactment, interpretation and relative emphasis of these characteristics depend heavily on context.

### *Emerging common grounds*

Across the lesson discussions, participants associated HQMI with mathematical integrity, student engagement, cognitive activation, responsiveness, representation, communication and attention to students' thinking. Underlying these characteristics was a shared emphasis on *engaging students meaningfully with mathematics* rather than merely *keeping them busy with activities*. Participants highlighted several ways to support such engagement: making mathematical content visible, connecting multiple representations and solutions, creating opportunities for higher-level thinking, exploring students' understanding, and using teacher moves to formalise mathematical ideas. The dimensions the groups subsequently proposed reflected these priorities, including cognitive activation and mathematical richness, a conceptual rather than solely procedural focus, adaptivity, discourse and communication, and, in some contexts, equitable access, identity and agency.

The two contrasting lessons in Session 1 nevertheless showed that these shared qualities can take *different observable forms*. Both lessons were regarded as engaging students in mathematics, but the US lesson relied more on individual communication and student-to-student interaction, whereas the Indian lesson used more teacher-led and whole-class interaction. Participants also contrasted student-centred and teacher-led approaches; complex or realistic contexts and routine or textbook problems; and different forms of questioning and representation. These comparisons suggested that *differences in visible pedagogy* do *not necessarily* indicate *differences in instructional quality*.

### *Productive tensions across contexts*

A central tension concerned the relationship between *universal dimensions of quality and culturally situated enactments*. Collaboration, classroom management and instructional support, for example, may carry different meanings in different educational settings. Participants contrasted expectations regarding student interaction and classroom behaviour in Germany and China, and noted that addressing heterogeneity may take on different importance depending on a classroom's linguistic and performance diversity. These examples supported the hypothesis that cultural variation may be most apparent in the *surface structures* of instruction, while deeper structures of mathematical quality may be more widely shared across contexts.

These contextual differences also complicated *what counts as evidence of student learning and participation*. Participants repeatedly asked how teachers and observers can know what students are thinking, particularly when some students do not speak or when interaction takes the form of recitation. They also identified a tension between personalised attention and the collective nature of classroom instruction: efforts to account for every learner could privilege individualisation at the expense of the classroom community.

### *Refining how HQMI is characterised*

These discussions point towards *refining, rather than simply expanding, a checklist of dimensions*. First, HQMI needs to be interpreted in relation to instructional goals. Participants cautioned that instruction cannot be evaluated independently of these goals, which differ across countries and may also vary across lesson and learning phases. Second, the dimensions need greater *mathematical specificity*. Frameworks

should attend to particular mathematical content and practices—including modelling, problem solving and representations—as well as to the gap between the mathematics being taught and students' existing mathematical understanding. Third, HQMI may be better understood as a set of *interacting processes* rather than as a collection of independent dimensions. Participants therefore questioned how dimensions relate to one another—for example, whether classroom management enables cognitive activation and whether moderation or mediation among dimensions should be considered. This process-oriented view also extends attention beyond observable enactment to the interconnected work of planning, teaching and assessment, including teachers' less visible professional judgement and noticing.

**Concluding Remarks**

Taken together, the Working Group discussions suggest that HQMI is best characterised not through a universal prescription of visible teaching behaviours, but through deeper qualities of mathematical learning and teaching. The enactment of these qualities must be interpreted in relation to mathematical content, instructional purposes, learners, lesson phases and cultural and educational contexts. Such a characterisation preserves meaningful common ground across settings while recognising multiple legitimate manifestations of high-quality mathematics instruction worldwide.



# VOCATIONAL MATHEMATICS EDUCATION – AN EXTENSIVE, YET UNDERSTUDIED RESEARCH AREA

Authors: Antonella Montone; Michele Giuliano Fiorentino; Pauline Vos; Bettina Dahl; Richard Voss




*Working Group conveners at PME49: "Vocational Mathematics Education – An Extensive, Yet Understudied Research Area".*

Vocational Mathematics Education (VME) concerns a large and diverse population of learners, yet it remains comparatively under-researched within mathematics education. The Working Group at PME49 was established to create an international space for discussing how mathematics is taught, learned, and used in vocational education, and for identifying promising directions for future research.

The Working Group built on the observation that VME differs considerably across national contexts. Depending on the country and vocational pathway, mathematics may resemble the curriculum offered in more theoretically oriented programmes, may be closely connected to vocational practices, may focus on mathematical literacy, or may combine these approaches. At the same time, many learners entering vocational education have experienced previous difficulties or failure in mathematics, sometimes accompanied by discouragement, anxiety, disengagement, or dropout.

Across the two sessions, participants from different countries and educational contexts were invited to map and compare their experiences with VME. The discussions addressed the role of mathematics in vocational programmes, differences between vocational and more theoretically oriented mathematics education, collaboration between mathematics and vocational teachers, teacher competences, and theoretical perspectives that may support research in this field.

The international comparison revealed substantial differences in how vocational education is organised and how mathematics is positioned within it. At the same time, several common concerns emerged. One discussion group, including participants from Italy, Norway, and the United States, noted that vocational students may still encounter mathematics through relatively traditional curricula. Participants reflected on how students with negative previous experiences of school mathematics may become disengaged from the subject and, in some cases, from education more broadly.

Mathematical modelling emerged as another important theme. Participants discussed examples related to cost of living and everyday professional decision-making. One example concerned an Uber driver and the reasoning involved in deciding whether accepting a particular fare or working opportunity would be worthwhile. This prompted a broader discussion about how frequently practitioners in vocational fields engage in mathematical modelling in their everyday work, even when they do not explicitly identify what they are doing as mathematics.

The discussions also highlighted the importance of risk-taking, experimentation, and learning from mistakes. Participants considered the educational value of allowing learners to test assumptions, make

decisions, evaluate outcomes, and revise their reasoning. In this context, George Box's observation that "all models are wrong, but some models are useful" captured an important aspect of modelling in vocational and real-life contexts: the aim is not necessarily to construct a perfect representation, but one that is meaningful and useful for a particular purpose.

A further topic concerned the relationship between mathematics and vocational identity. The original rationale for the Working Group emphasised that learners in VME may identify strongly with their vocation rather than with being students of mathematics for its own sake, and that theoretical frameworks for VME therefore need to bridge mathematics and vocational practices. The discussions at PME49 reinforced the importance of investigating how mathematics can be connected to authentic professional practices without reducing either the mathematics or the vocational activity to artificial classroom exercises.

Despite the considerable differences between vocational education systems internationally, one unfortunate commonality identified in the discussions was the persistent stigma associated with vocational pathways. Participants recognised that vocational education may still be perceived as having lower status than more academically oriented routes. This raises important questions concerning students' mathematical identities, their educational trajectories, and the role that mathematics education can play within vocational programmes.

The two sessions generated rich discussions among participants from different parts of the world (all the countries the participants came from: Denmark, Norway, the Netherlands, Italy, USA, South Africa, India) and showed the value of bringing together researchers working in a field that remains extensive but understudied. The Working Group concluded with a shared commitment to strengthening research in Vocational Mathematics Education, developing international comparisons, further examining appropriate conceptual and theoretical frameworks, and continuing the collaboration initiated at PME49.

INTERNATIONAL GROUP FOR THE
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# EXAMINING MATHEMATICAL SENSE MAKING THROUGH POETIC APPROACHES BEYOND LINGUISTIC DATA

Authors: Aehee Ahn; Julianne Gerbrandt; Sheena Tan; Pauline Tiong; Sue Staats; Rachel Helme

PME49 Working Group — Examining Mathematical Sense Making Through Poetic Approaches Beyond Linguistic Data — was the third PME working group focusing on poetic inquiry, following the sessions in PME46 (2023) and PME47 (2024). The poetic inquiry working groups aim to create a community among mathematics education researchers interested in methods of representing and analysing communicative patterning in mathematical experiences and have been guided by two high level principles. First, we see ourselves as a place for participants to explore the distinct purposes, methods and underlying philosophies of poetic methods. We do not aim to prioritize one scholarly position on mathematical poetics over another. But we do wish to examine each poetic inquiry method in connection with its ontological stance on what generates poetic expressions. For some, patterning of expressions generates communication itself, for others, it arises from a researcher's attention to form, and for others still, it emerges somewhere between the researcher and participants. We call this stance poeticity and we expect each method to identify it differently. A second principle is that the PME working group circulates leadership positions each year. We hope that this will become a way for PME attendees to connect a wide range of research interests to mathematical poetic methods. Thus far, the PME poetic inquiry working groups have informed dissertations and articles under review. Additionally, participants from the 2024 Working Group, Pauline Tiong, Aehee Ahn, and Sheena Tan, developed and led a parallel working group on poetic methods in mathematics education at EARCOME 2025. This year's PME working group engaged twenty participants, besides the presenters, making it the largest poetic methods group thus far.

This year's working group supports interest in a broad range of patterned experiences, such as the resonances of emotions experienced between researchers and research participants, conversational echoes flowing through collaborative conjecturing, and rhythms in embodied aspects of sense making, over the two sessions. In the first session, we had fifteen participants and we began by inviting everyone to share what had drawn them to the working group. Their curiosities were wide-ranging: theatre, alternative methodologies, sensitivity to rhythm, representing movement and gesture, systemic functional linguistics alongside gesture, feelings, comics, and art-making and choreography. Several were intrigued by the notion of working "beyond linguistics." This breadth suggests that interest in poeticity within mathematics education research extends well beyond poetry as a literary form.

We continued with a focus on feeling and noticing in the first session. Drawing on Faulkner (2019), we framed poetic inquiry as a relational, affective, and humanizing practice. In this practice, a researcher's empathy, discomfort, and resonance serve as analytical resources rather than biases to be bracketed and left unquestioned. We asked how poetic methods might make relationality, emotion, and everyday mathematical experiences visible in mathematics education research, and how researchers' affect might function as an analytic resource. To ground these questions, Julianne read aloud a found poem composed from a transcribed interview. She described the surrender-and-catch process (Prendergast, 2015) used to create it. One facilitator, taking part as a participant, shared her response to the transcript. Words addressed to you stood out to her, and she pictured the child hearing them. She felt sad and embarrassed for the parent, and then noticed negative feelings toward the parent. Participants then composed their own found poems from a longer excerpt in which both parent and researcher voices appear.

The discussion moved in directions we had not anticipated. Participants wanted to know more about the mathematics behind the sample poem, which suggests that context shapes how one engages with a found poem. They also attended closely to their own decisions about what to catch and how to arrange it in a poetic form. One participant with a background in linguistics observed that "it was already poetry," pointing to rhythms already present in everyday speech. This led us to consider the ontology underlying

poetic work: whether poeticity is made by the researcher, found in the data, or emerged between the two. Another participant, interested in comics, composed a found poem in the first session and returned in the second session with an AI-generated comic built from the poem's material. This blending of methods further raised the question of whether comics, already patterned through their panels, are amenable to poetics.

In the second session, we had five new participants joining us so we did a recap on the first session and some reflections we had as a group. Following which, we shared how the notion of poetic diagramming has been developed from the work of Aehee, Pauline and Sheena that started in PME47. Based on the ideas of embodiment by de Freitas and Sinclair (2012), we understand diagrams and gestures beyond static representations, as dynamic forces shaping distinctive rhythms of meaning making in mathematics. Hence, we are interested in bringing alive how diagramming and gesturing operate as intertwined elements of embodied learning, with poetic diagramming serving as a methodological bridge. To illustrate some ways of translating gestures and drawings into poetic forms, we began by watching a muted video of students working on a problem together to bring attention to the non-linguistic aspects in students' discussion. What stood out from this starter activity was the variety of embodiment aspects different participants noticed, beyond what we attended to. For example, one participant was drawn to the larger scale movements of the students as they seemingly moved in a rhythmic manner while zooming in and out to view the diagrams. This prompted discussions around the potential richness of poetic approaches in illustrating different forms of embodied learning.

Overall, the conversations with participants in this year's working group offered opportunities for us to reflect on and expand the notion of poeticity in mathematics education and mathematics education research. Some participants initially associated poetry with literary production, while others brought curiosity in terms of how poetics could contribute to mathematics education research. With the use of diagrams, movements, and other non-linguistic forms emerging as possible ways of expressing and attending to mathematical rhythms, productive questions were posed by the participants. One example was whether these forms represented the mathematics, students' responses, or researchers' interpretive choices. As facilitators in this working group, we see these curiosities and responses as openings for further collective exploration. They encourage us to make space in future dialogues for participants to experiment with various forms of poems and discuss the choices in creating and interpreting them. As a community interested in mathematical poetic methods, we hope to exchange ideas with researchers about their own methods and approaches to poeticity, including those which may not be currently described as poetic. We also welcome opportunities to develop further working groups at future PME to continue these conversations. If anyone is keen to be added to our mailing list of researchers interested in mathematical poetic methods, please contact Sue Staats, staats@umn.edu.

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INTERNATIONAL GROUP FOR THE PSYCHOLOGY OF MATHEMATICS EDUCATION

# INTERNATIONAL PERSPECTIVES ON PROOF, PROVING AND RELATED ACTIVITIES

Authors: Nadia Azrou; Miglena Asenova; Michael Fischer; Yusuke Shinno; Fabio Simas

This Working Group (WG) addresses the critical need for cross-cultural comparative research on the structural, linguistic, and curricular dimensions of mathematical argumentation. Moving beyond broad cultural generalizations or literal translations, the WG argues that terminology like "proof" and "argumentation" must be examined operationally within specific educational settings to capture what is actually taught, expected, and recognized in classroom practice. Related actions like conjecturing, pattern identification, and checking are treated as irreducibly distinct components of mathematical activity. The long-term purpose of the WG is to establish an international research network to facilitate collaborative empirical projects, eventually leading to joint PME Research Forums and beyond.

## STRUCTURE OF THE SESSIONS

The WG executed two highly collaborative sessions at PME 49. Session 1 opened with a brief history of this working group at past conferences, introduced by David Reid, who has been leading the group. This introduction was followed by the sharing of a recent related study by Horacio Solar on how teacher leaders notice teachers' support for mathematical argumentation. During the subsequent group work, participants discussed selected themes from the seven proposed by the organizers and recorded their reflections on a Padlet. In preparation for the second meeting, the organizers synthesized these contributions into five core themes.

Session 2 shifted from thematic exploration toward concrete problem formulation and international collaboration. The session commenced with a brief methodological reflection on an exploratory cross-cultural terminology project mapping how mathematical definitions and native terms intersect across research traditions. Following this framing, participants self-selected into the five previously presented core themes. Each group spent 40 minutes identifying a specific research problem, formulating an associated research question, outlining methods, and considering potential next steps for collaboration. The session concluded with a plenary reporting block and a cross-thematic analytical synthesis.

## PROGRESS AND OUTCOMES

The primary outcome of the WG sessions was the development of five emerging themes for international research collaborations:

- Theme 1 (Language in Argumentation and Proof): Participants: N. de Sena Maier, C. Grisendi, H. Otani, D. Reid, N. Spillner (Contexts: Germany, Italy, Japan, Norway, Germany). This group focused on communication barriers that arise because explicit definitions are still interpreted through assumptions shaped by a reader's native culture. They outlined a possible comparative study utilizing a common classroom vignette showing mathematical knowledge construction, asking mathematics education researchers from different linguistic and cultural contexts to section, describe, and classify the activity to reveal underlying criteria.
- Theme 2 (Logic in Argumentation and Proof): Participants: T. Ando, S. Lundt, A. Matteucci, Y. Tsujiyama, C. Zámbó (Contexts: Japan, Germany, Italy, Japan, Hungary). This group addressed the disconnection between formal textbook logic and fluid proving activity. Drawing on different national pathways—such as explicit logic in Italy, a strong emphasis on deductive reasoning in Japan, and combinatorial reasoning in Hungary—they outlined a comparative textbook and curriculum analysis approach.
- Theme 3 (Teacher Education in Argumentation and Proof): Participants: M. Fung, M. Pesen, M. Piñeros Rodríguez (Contexts: USA, Turkey, Switzerland). This group focused on understanding what "counts" as proof for prospective teachers across cultures. They outlined an empirical protocol where teacher

candidates evaluate a curated portfolio of proposed proofs displaying varying formats, completeness, and types of justification to isolate the features that dictate proof acceptance globally.

- Theme 4 (AI and Argumentation and Proof): Participants: S. Bödefeld, T. Evans, K. Kirsten, M. Pinto, S. Quiroz (Contexts: Germany, New Zealand, Germany, Brazil, Mexico). Concerned that students may use generative AI to obtain finished proofs without engaging in the underlying reasoning, the group proposed comparing three instructional conditions: conventional instruction, open generative AI, and a purpose-designed AI tutor providing step-by-step hints. The study will examine differences in learning gains and students' capacity to validate proofs across these conditions.
- Theme 5 (The Rationale for Teaching Argumentation and Proof): Participants: E. Knuth, S. Neuhaus-Eckhardt, H. Solar, M. Yannotta (Contexts: USA, Germany, Chile, USA). This group framed the purpose of proof as a variable that depends on who is being asked (mathematicians, university instructors, schoolteachers, or students). Comparing centralized, argumentation-based frameworks in Chile with decentralized systems in Germany and the US, they formulated routes to examine how cross-disciplinary argumentation can help students build a genuine intellectual need for proof, focusing specifically on students' perceptions of the purpose of proof and the relationship between argumentation in mathematics and other academic disciplines.

**PLANS FOR FUTURE COLLABORATIVE WORK**

The significance of this WG lies in its highly connected approach. As established during the closing synthesis, the five themes are distinct but deeply interconnected: language shapes logical terminology (Themes 1 & 2); textbook enhancements require teacher preparation to make logical structures visible (Themes 2 & 3); the widespread availability of AI-generated proofs makes students' logical error-catching and proof validation far more critical (Themes 2 & 4); teacher education needs depend on the intended school purposes of proof (Themes 3 & 5); and AI implementation must align with broader instructional goals (Themes 4 & 5).

We hope that several sub-groups will further develop their discussions into collaborative research projects and shared data collection instruments, including a common vignette collection, a textbook analysis matrix, and the AI tutor guidelines. Moving forward, the WG is transitioning into an active international research network, with the aim of facilitating collaboration and contributing to future PME conferences.

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# DEVELOPING FRACTION AND ALGEBRAIC REASONING: SUBCONSTRUCTS, SCHEMES, AND TRANSITIONS IN LEARNING AND TEACHING

Authors: Zelha Tunc Pekkan; Keiko Hino; Gulseren Karagoz Akar; Pedro Ivars; Ellef Fange Gjelstad

This working group marked a new initiative within PME and brought together approximately 40 participants from diverse international contexts, including Japan, Türkiye, Norway, and other European countries. The group was created to foster dialogue around the development of fraction and algebraic reasoning, with particular attention to theoretical constructs such as units coordination, quantitative reasoning, fraction schemes, and their implications for learning, teaching, and research.

The first session began with an introduction to the goals of the working group and the themes that would guide our discussions. Four short stimulus presentations provided a foundation for the collaborative work that followed.

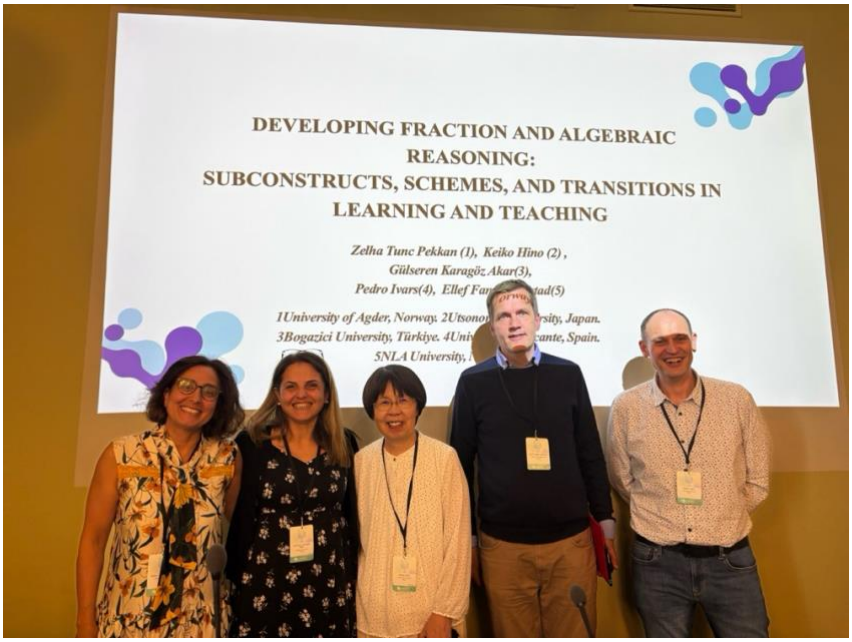
The first stimulus focused on units coordination and fraction knowledge. Zelha Tunc Pekkan introduced the goals of the group and discussed theoretical constructs related to number schemes and units coordination. Participants then examined a short video of a seven-year-old child engaged in counting activity. This served as a shared exercise in observing children's mathematical activity and considering how researchers and teachers construct models of children's mathematical thinking.

The second stimulus, led by Gülseren Karagöz Akar, focused on quantitative reasoning and ratios. The presentation highlighted important connections among quantitative reasoning, proportional reasoning, and the development of multiplicative thinking.

The third stimulus, led by Keiko Hino and Pedro Ivars, explored pre-service and in-service teachers' fraction knowledge as a foundation for algebraic reasoning. Pedro presented work on how learning trajectories can support prospective teachers' noticing of children's mathematical understanding. Keiko shared research examining teachers' multiplicative concepts and how these constructs influenced their problem-solving activity in algebraic contexts.

The fourth stimulus, led by Ellef Fange Gjelstad, addressed methodological approaches for investigating fractions and algebraic reasoning. Drawing on his own research, Ellef demonstrated how eye-tracking technology can be used to investigate units coordination and provided examples inspired by work building on Norton et al. (2015).

The presentations generated lively discussion and engagement from participants. At the end of the first day (see Picture 1), attendees selected two themes for more focused collaborative work during the second day. One topic they chose was to examine Japanese curriculum materials with Gülseren Karagöz Akar taking the lead. The second topic was interview analysis on understanding the connections among fraction knowledge, units coordination, and algebraic equations through teacher data from Japan and Türkiye, led by Keiko Hino and Zelha Tunc Pekkan.




*Picture 1: Working group organizers at the end of the first day*

During the second day, participants worked in smaller groups around shared data and tasks. In the curriculum materials task, participants examined the Japanese Course of Study, Teachers' Guides, and textbook materials through the lenses of quantitative reasoning, units coordination, covariational reasoning, and multiplication. After discussing stages of units coordination, participants analyzed selected textbook activities and considered how these tasks supported students' mathematical development (see Figure 1). The discussion was enriched by the participation of Japanese teachers (participants) who shared perspectives on how such activities are adapted and enacted in classroom.

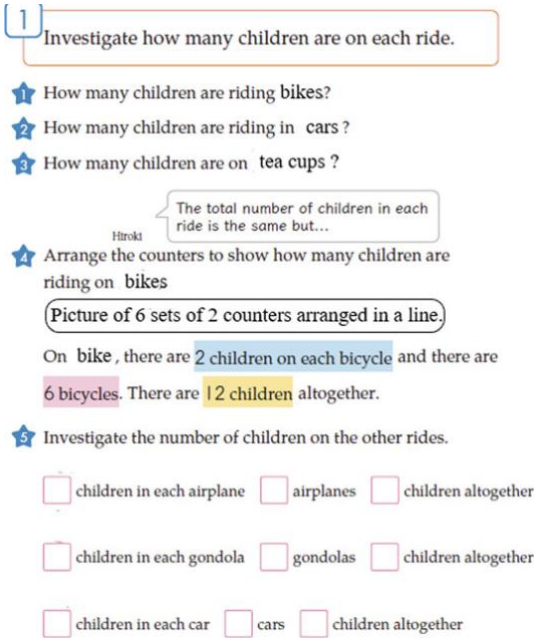



*Figure 1: An activity introducing multiplication through a real-life situation which was an amusment park in the previous page(Fujii & Iitaka, 2012, Grade 2, p. B5) ( Karagöz Akar, Watanabe & Turan, 2022, p. 119).*

In the second task, participants analyzed interview transcripts and video data from one Japanese and one Turkish teacher who had been interviewed using a common protocol. The discussion focused on how teachers' understanding of units coordination and fraction knowledge supported their reasoning about relationships between quantities and the construction of algebraic equations. A central problem involved

determining how much area could be painted with one deciliter of paint when three-fourths of a deciliter covered one square meter. Participants used a stages framework for units coordination to interpret the teachers' reasoning and to discuss methodological approaches for analyzing such data.

One of the most rewarding outcomes of the working group was the depth of discussion that emerged across different research traditions, national contexts, and methodological perspectives. Participants actively exchanged ideas, challenged interpretations, and explored possible connections among fraction learning, quantitative reasoning, proportional reasoning, and algebraic thinking. The collaborative atmosphere created opportunities for both established and emerging researchers to contribute to the conversation.

The working group concluded with a discussion of future directions. Several smaller collaborative groups emerged around shared interests, and participants expressed enthusiasm for continuing their work beyond the conference. Plans were discussed for collaborative research projects, conference submissions, and ongoing international dialogue. There was strong interest in continuing this initiative at future PME conferences, and participants emphasized the value of having a dedicated forum for exploring the relationships among fractions, quantitative reasoning, and algebraic reasoning from multiple theoretical and methodological perspectives.

As a new PME initiative, the working group successfully created a space for international collaboration and scholarly exchange. We were encouraged by the high level of participation, the quality of discussions, and the enthusiasm for future collaboration, and we look forward to building on this momentum in the years ahead.

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# PROOF ASSISTANTS AS CATALYSTS TO DISCUSS ABOUT PROOF IN MATHEMATICS EDUCATION RESEARCH

Authors: Cecile Ouvrier-Buffet; Carola Manolino; Julien Narboux; Antoine Meyer

A proof assistant is a software environment that enables users to construct a formal mathematical proof step by step. Each step is checked and validated by the system according to a formal logical framework. Proof assistants such as *Lean* are increasingly used in mathematical research and computer science, and are also used for educational purposes. However, their use raises important questions for mathematics education: What is gained or lost when a proof is produced in interaction with a machine? Which aspects of proving are made explicit, constrained, or delegated to the system? How does the design of the interface impact students' and teachers' understandings of proof?

This working group brought together researchers interested in proof, proving, and the transition from secondary to university mathematics. Although the group was small, its participants came from different countries and brought varied experiences of mathematics education, research, and proof. This diversity was particularly interesting for making visible different ways of understanding, producing, and validating a mathematical proof.

Participants were invited to share their "favourite" proofs and to work on a short statement: *the sum of two odd integers is even*. This paper-and-pencil activity highlighted a variety of registers of representation, proof structures, levels of explicitness, and criteria for evaluating whether a proof is acceptable. These differences pointed out the existence of distinct cultures of proof among researchers and teachers.

Participants then explored similar mathematical statements using *Yalep* (try it! http://vm-lean4web.nova.u-ga.fr/#project=PME_Helsinki), an educational language and interface built on *Lean*. *Yalep* is designed to make formal proof more accessible by providing a controlled natural language and by hiding some of the technical complexity of the underlying proof assistant. Nevertheless, the activity revealed both technical and conceptual obstacles. The experience showed how demanding formal proof can be in such a digital mathematical environment, even when the initial mathematical argument is elementary.

The contrast between the paper-and-pencil and *Yalep* activities opened a broader discussion. The participants' responses reflected not only different cultures of proof, but also different relationships with the machine and with the proof assistant. A formal proof is not only a proof transferred into a digital interface: the environment changes what must be stated, how it must be stated, and how the validity of an argument is established. It therefore provides interesting discussion to investigate different conceptions of formal proof, mathematical language, proof structure, and validation.

Publications on proof assistants in mathematics education just begin: the existing literature is relatively limited and largely focused on *Lean*. Few studies investigate the design of situations combining proof assistants with paper-and-pencil proof, the teachers' practices when implementing proof assistants in their courses, and the impact of proof assistants on students' practices of proving.

The working group sessions thus generated a set of questions for further investigation: What kind of knowledge do teachers need in order to design and orchestrate learning situations involving proof assistants? How can proof assistants be technically well-integrated into mathematics education without reducing proof to formal verification? What kinds of connections can be developed between machine-checked proofs and ordinary mathematical writing?

The activities and the discussions of these working group sessions will constitute a corpus for a future working group at PME.

A fundamental aim is here to contribute to a dialogue between mathematics education research and the communities developing proof assistants, while keeping the mathematical educational questions - what students learn, how teachers teach, and what counts as proving - at the centre of the discussion.

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**Funding details.** This work was supported by ANR (French National Research Agency) under Grant - ANR-23-CE38-0009.

# MATHEMATICAL LEARNING IN INTEGRATED STEM INQUIRY: DESIGN AND ASSESSMENT CHALLENGES

Authors: Sasha Wang; Marta Megiera

This working group addressed persistent theoretical and methodological challenges regarding how mathematical learning is designed, enacted, and assessed within integrated STEM inquiry. While integrated STEM education often emphasizes science, engineering, or technology, mathematics often serves as an implicit or supporting tool rather than an explicit object of inquiry. Over two 90-minute interactive sessions, participants established theoretical foundations, analyzed real-world case studies, formulated key design and assessment principles, and identified critical future research directions.

The first session aimed to establish a shared theoretical foundation and identify key challenges in integrating and assessing mathematics in STEM inquiry. The discussions were framed using three complementary theoretical perspectives:

1. **Sociocultural Learning Theory** (*Vygotsky, 1978; Sfard, 2008; Cobb et al., 1990*)
    - Focus: Mathematical learning develops through social interaction, discourse, and participation in cultural practices.
    - Key Tension/Question: If students are not explicitly communicating mathematically or using explicit mathematical language during integrated STEM tasks, how can we ensure that mathematical thinking is shared, valued, and internalized rather than remaining hidden or implicit?
2. **Design-Based & Engineering Design Learning Theories** (*English, 2016; NRC, 2014; Razzouk & Shute, 2012*)
    - Focus: Iterative cycles of problem definition, modeling, testing, optimization, and communication.
    - Key Tension/Question: Traditional mathematics education builds on sequential, cumulative learning trajectories, while design cycles foster emergent, non-linear mathematical reasoning. Tasks must be structured so that mathematics is a core disciplinary practice rather than an optional add-on tool.
3. **Complexity and Systems Perspectives** (*Bakker et al., 2015; Wenger, 1998; Law, 2004*)
    - Focus: Learning is non-linear, situated, socio-material, and distributed across learners, peers, physical tools, and digital representations.
    - Key Tension/Question: Traditional pre- and post-tests fail to capture distributed and dynamic mathematical learning. Assessments must recognize mathematical thinking as it unfolds multimodally across gestures, artifacts, and discourse.

Participants engaged in a Think-Pair-Share to identify moments when mathematics was either visible or unexpectedly missing in integrated STEM activities. Theoretical presentations followed to provide grounding frames for discussion. In small groups, participants then shared their integrated STEM inquiry experience and probed for explicit vs. implicit mathematics, assessment challenges, and alignment with theoretical lenses (e.g., making implicit discourse visible, resolving tension between iterative design and linear curricula, and measuring distributed learning).

The second session focused on collaborative analysis and assessment. Participants analyzed concrete case studies to evaluate mathematical reasoning and develop core design/assessment principles. Cases discussed included:

1. Bridge Project (Design-Based Lens): Examined student iterative physical building, dialogue, and reflections (e.g., trapezoidal stability) to evaluate how task design can move math from implicit background work to explicit structural justification.

2. Robotics Challenge (Sociocultural Lens): Analyzed transcripts showing how teacher interventions naming explicit mathematical objects ("the angle in code") shifted student behavior from trial-and-error to purposeful calculation and discourse.
3. Water Filtration Project (Complexity Lens): Analyzed non-linear data collection charts, peer explanations of flow rates, and video gestures to explore multimodal assessment beyond traditional written tests.

Participants then shared their assessment insights, highlighting the trade-offs between static written reflections and dynamic multimodal evidence. The knowledge-building discussions led to proposed core design principles for mathematics-centered integrated STEM to guide future curriculum design and assessment. These included:

1. Make the mathematics explicit: Explicitly name mathematical objects, concepts, and practices upfront. Design opportunities where students explicitly communicate and reason about mathematics.
2. Position mathematics as co-central (Not supporting): Structure tasks so that mathematical reasoning is required to solve the core problem, preventing math from becoming subordinate to science or engineering.
3. Honor both iterative design and mathematical rigor: Couple iterative design cycles (*design, test, analyze*) with explicit reflection cycles where students formalize and articulate stable mathematical concepts.
4. Assess mathematical thinking multimodally and longitudinally: Collect evidence across discourse, representations (drawings, graphs, code), and gestures over extended timeframes rather than relying strictly on pre/post snapshots.
5. Create artifacts that make thinking visible: Utilize structures, code comments, annotated sketches, and peer explanations to externalize and assess the quality of reasoning embedded in student artifacts.

The working group concluded by defining five priority areas for post-conference research and collaboration:

1. Measurement & Validity: How to reliably measure mathematical thinking distributed across modalities and time.
2. Transfer & persistence: Investigating whether conceptual understanding developed through integrated STEM inquiry transfers to new contexts and persists longer than traditional instruction.
3. Equity & access: Ensuring integrated STEM tasks make all students' mathematical reasoning visible, valued, and supported—particularly for historically marginalized learners.
4. Teacher preparation & practice: Understanding the professional development, pedagogical knowledge, and identity shifts needed for educators to balance math and STEM integration.
5. Design principles at scale: Codifying frameworks into practical teacher toolkits and adapting principles across diverse grade levels and resource contexts.

To continue the work that began in the working group, the organizers invited interested participants to collaborate on a post-conference joint publication on design principles, case studies, and assessment tools.

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# ECOLOGICAL METHODOLOGIES FOR MATHEMATICS EDUCATION RESEARCH

Authors: Tracy Helliwell; Tracy Weston; Alf Coles

Research frameworks orient inquiry, drawing on particular principles and assumptions that guide action. They simultaneously enable and constrain how educational research is conceptualised and justified, and impact the questions we ask, along with the methodologies taken to move towards understanding. In this working group, we explored an emerging framing in mathematics education that has been referred to as ecological (e.g., Weston, 2026) or socio-ecological (e.g., Coles, 2023), building on a previous Research Forum at PME (Amico et al., 2023). We use the term ecological to centre the study of relationships (Begon et al., 2012) between organisms (including humans), and their environments (e.g., natural, physical, social, cultural, political, material). There are several strands of thinking within mathematics education which have forged awareness of ecological relations, including critical mathematics education, Indigenous scholarship, ethnomathematics, feminist thinking, de-colonizing, new materialism, enactivism, socio-political research, and others (Makramalla et al., 2025).

Throughout the working group, our aims were to:

- explore the consequences of an ecological framing on research design and research practices in mathematics education.
- interrogate current and articulate new research practices and principles from an ecological perspective.

The first session focused on observing relations. We watched a video recording of a one-on-one interaction between a teacher and student and explored what it could mean to observe the relations present, without focusing (first) on the individuals. Some possible ways of doing this that emerged were to analyse: the rhythm of actions; shifts in relative body positioning; relations between thought and action; pauses. And, in one reflection on the session, a participant identified a seeming paradox that as soon as we highlight a relation as a focus for observation, there is a danger (or inevitability?) that we objectify the relationship.

In the second session, the focus shifted to broader methodological practices and how they might become more ecological. We offered the following prompts:

- Relations: What could it mean for your research if the unit of analysis was relations (as opposed to subjects or objects)?
- Scales: At what temporal and spatial scales could you be researching phenomena?
- Knowing: Who or what could be recognised as a knower within your research?
- Listening: In what ways could you employ deep listening practices as part of your research? Who/what could you listen to?
- Boundaries: How could you design your research in a way that attends to emergence, non-linearity, ambiguity, and complexity, and how do these considerations shape the boundaries of how and what you study?
- Distinctions: What distinctions could your research be generating and which distinctions could it aim to unsettle or collapse?

If we assume relations (1) are the basic unit of being in the world, can relations become our unit of analysis? Is this adequate? How do we handle the (infinite) complexity of relations across scales (2), for example between society and mathematics, across time, in different places? Can we identify tensions? In some Indigenous communities, knowers and knowing (3) can extend to the land itself (as a researcher).

In working on analysing a dialogue, one group tried to notice connections between statements, which required a disciplined way of listening (4), a deep listening. Boundaries (5) are relevant to representing relations, and the move from a focus on subjects to a focus on relations. Emergence seems to describe systems of relations seen from the outside. How do we represent complexity? What distinctions (6) are we creating and what distinctions are we collapsing? Which distinctions are harmful or not, and for whom?

As organisers, we were grateful for the engagement and insight of participants. Developing ecological methodologies is work that is on-going and we hope that discussions will continue at future PME conferences.

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# AI-BASED MATHEMATICS TEACHING SIMULATIONS: PROMISE, PITFALLS, AND RESEARCH DIRECTIONS

Authors: Gil Schwarts; Sigal H. Rotem; Corey Webel; Nadav Marco; Raz Harel; Sharon Calor

AI-based teaching simulations are emerging as a new form of approximation of practice (Grossman et al., 2009) in mathematics teacher education and as a methodological tool for mathematics education research. Building on traditions of rehearsing teaching practices through clinical and digital simulations (e.g., Dieker et al., 2014; Herbst et al., 2022), generative AI makes it possible to create environments in which teachers can engage in open-ended dialogue with simulated students. Such environments offer possibilities for repeated, on-demand, and relatively standardized opportunities to engage with challenging aspects of mathematics teaching. At the same time, they raise important questions concerning what is practiced and represented, and what is lost, when mathematics teaching and learning are simulated through generative AI. Throughout the working group, our aims were to: (1) Examine the pedagogical and methodological affordances of AI-based simulations; (2) Analyze key constraints, including environmental costs, disembodiment, authenticity, and bias; and (3) Develop principles and collaborative research directions for their design, use, and study.

The first session focused on experiencing and comparing two AI-based teaching simulations. The first addressed teacher noticing. Participants interacted with an AI-generated student around a situation involving algebraic reasoning and discussed how the simulation might support identifying, interpreting, and responding to students' mathematical thinking (Rotem & Chytas, 2026). Participants were then introduced to MRT-Sim (Schwarts & Czaczkes, in press), an environment designed around mathematically responsive teaching and one-on-one interaction with a simulated student. Participants explored aspects of the environment and discussed how differences between the two simulations might create different opportunities for teacher learning and research.

Several issues emerged from these discussions. Participants considered the relationship between authenticity and standardization: representing a particular student through a name, picture, and handwritten mathematical work could contribute to perceived authenticity, while a more constrained environment could enable greater standardization across interactions. They also discussed transparency, contrasting a simulation in which the underlying prompt was visible and modifiable with one in which the configuration of the simulated student was less apparent.

Participants also considered which aspects of teaching different simulations approximate. A one-on-one interaction around a predefined problem may provide opportunities to practice responding to student thinking while offering fewer opportunities for identifying noteworthy moments within complex classroom activity. This led to discussion of simulations involving multiple students and of the mathematical knowledge needed to sustain productive dialogue. Participants further questioned what forms of feedback should accompany simulation: plausible student responses do not necessarily provide teachers with information about the quality of their instructional moves.

The second session began with a third simulation focused on preservice teachers' one-on-one questioning practices (Lee et al., 2026). Participants interacted with simulated students working on fraction problems and considered questions that might elicit and extend students' mathematical thinking. Discussion focused on what prospective teachers might learn through these interactions. Having engaged with three approaches to AI-based teaching simulation, we shifted toward a more explicitly critical examination of AI simulations. Participants worked in groups around three issues: environmental implications of generative AI (led by Sigal); embodiment and disembodiment (led by Nadav); and representations of students in AI-generated interactions (led by Corey).

The discussion of embodiment and disembodiment considered what happens when mathematics teaching—a practice involving gesture, gaze, movement, diagrams, objects, and spatial interaction—is approximated primarily through textual dialogue. Participants considered both what this reduction makes possible and what it omits, and how simulations might connect more productively with embodied classroom teaching. The group examining representations of students considered how simulated students necessarily foreground some aspects of students and their identities while omitting or deemphasizing others. Participants discussed the implications of these representational choices and possible guidance for simulation designers. A third group considered the environmental implications of generative AI, bringing questions of energy use into consideration alongside its potential educational value.

The working group concluded with a whole-group synthesis and discussion of future research and collaborations. Across the two sessions, the discussions highlighted design considerations concerning openness and standardization, transparency, feedback, representation, and embodiment. Rather than asking only how closely a simulation reproduces classroom teaching, an important question is what aspects of practice a simulation is intended to approximate, for what purposes, what its design makes possible to learn and study, and what it necessarily leaves out.

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# VALUES FOR MATHEMATICS EDUCATION: NEXT STEPS

Authors: Ralf Erens; Wee Tiong Seah; Julia Hill; Camilla Spagnolo; Ana Isabel Silvestre; Jodie Hunter

This Working Group has been a follow up to previous PME working groups (namely, PME36 in 2012, and PME39 in 2015), which resulted in two Springer books (Clarkson et al, 2019; Dede et al, 2024) and many years of sustained RR presentations at subsequent PME conferences. This group has worked on similar follow-up activities. The goals for the current Working Group have been:

· To re-conceptualize existing theories/concepts on values and related constructs, by exploring emergent frameworks and personal research experiences.

· To formulate researchable questions in the field, and to explore and develop potential methodologies that address these questions.

**Theoretical background**

A more comprehensive understanding of how mathematics is even better taught and learnt requires the acknowledging that the human mind is tripartite in nature, involving cognition, affect, and conation, and that all three aspects can – and need to – be developed for everyone to learn mathematics and be numerate while experiencing a sense of well-being. Values constitute a key conative variable, underlying motivation and drive (Seah, 2019). DeBellis and Goldin (2006) highlight the deeply rooted nature of values, describing them as “personal truths” that inform long-term priorities.

Recently, within mathematics education research, there has been increasing interest in the development of theories and research approaches that can account for shaping decisions and behaviours and can shed further light on the complex relationship between values and affective variables (e.g. beliefs). A dynamic interplay between teaching and learning highlights the potential of values to enhance ethical and effective mathematics education (Chiu & Seah, 2024). Values have also been instrumental in the promotion of mathematical wellbeing, an affective variable, for example.

Proceedings of the Working Group sessions: There were about 30 participants in the first session of the Working Group. This first session began with introductions and an exchange of participants’ experiences with values and values research in mathematics education. Particular attention was given to the theoretical constructs that underpin research on what teachers and students value in mathematics teaching and learning. Participants shared their respective areas of expertise and discussed how their different theoretical and methodological backgrounds shape the ways in which values are conceptualized and investigated. The discussion also considered perspectives from related disciplines, including psychology and cultural studies, and explored their potential contributions to values research in mathematics education. Participants’ personal and professional experiences provided a further basis for identifying common themes, differences, and complementary perspectives.

Building on these exchanges, the working group reviewed existing approaches to researching values in mathematics education and considered possibilities for extending current conceptual and methodological perspectives. This included discussion of potential new approaches and conceptualizations, such as the JEDI approach, as well as ways of strengthening the application of values research to educational practice.

In the next part of the first session, participants engaged in small-group discussions focusing on the further development of theoretical and conceptual frameworks. Particular emphasis was placed on frameworks capable of strengthening the interaction between theory and practice and, more broadly, on identifying directions for future research on values and valuing in mathematics education.

Building on the discussions and perspectives developed during the first session, the second session focused on identifying future directions for research on values in mathematics education. Working in groups,

participants formulated a set of researchable questions and considered which of these questions they would be interested in and able to pursue within their respective research contexts.

The groups then examined how these research questions might be developed theoretically and in terms of methodology. Discussions addressed the theoretical frameworks that could inform future studies, including the potential need to adapt or develop existing frameworks. Participants also considered appropriate methodological approaches and discussed what forms of data would be required to investigate the proposed questions.

Each group subsequently shared its ideas with the wider working group. The plenary discussion was used to identify common research interests, complementary areas of expertise, and opportunities for collaboration. Particular attention was given to establishing concrete next steps for continuing the work beyond the meeting. This included exploring possibilities for collaborative research and joint publications, with a potential special issue of the *Journal of Mathematics Teacher Education* discussed as one possible collective outcome.

As such, participants were mindful of the importance of keeping in touch with one another. While such communication has been facilitated through the Third Wave website over the years (which also acts as a database of members' publications), participants who were new to the website were given the opportunity to sign up. We will continue to develop the working group within, and beyond, the PME community.

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# DIVERSITY OF PERSPECTIVES AS A RESOURCE: CONNECTING IDENTITY THEORIES IN MATHEMATICS EDUCATION

Authors: Derya Sahin Ipek; Soryna Sabbah; Luca Picariello; Danai Dafnopoulou; Lara Gildehaus; Einat Heyd-Metzuyanim; Andreas Ebbelind; Annamaria Miranda

This working group brought together early-career and senior researchers interested in different theoretical approaches to identity research in mathematics education. This group grew from an international Identity Network in which doctoral, postdoctoral and senior researchers have been meeting to discuss theoretical, methodological and empirical issues in their ongoing studies. We explored how different perspectives conceptualise identity, how they relate to one another and how these differences matter when analysing empirical material. Approximately 25–30 participants took part in each session. Across the two days, the Working Group combined short presentations, group work and whole-group discussions.

### *Mapping perspectives on identity*

The first session used Darragh's (2016) landscape of identity research as an organising tool. Members of the organising team introduced their studies and explained how they conceptualised identity in their work. The studies drew on performative, narrative-biographical, participative and discursive perspectives, with some drawing on more than one. Participants then worked in three groups, focusing on narrative, participative and discursive perspectives, to relate the map to their own research interests.

Across the groups, participants discussed what different perspectives draw attention to, how they relate to different kinds of data, and where the boundaries between them might lie. In the narrative group, participants came from a range of research areas, and several were relatively unfamiliar with identity approaches. The discussion began with how identity concepts might connect with their own research and then moved to how storytelling and analytical focus may change across narrative and discursive readings, the nature of different forms of data, and how affect, emotions and beliefs might relate to identity research. In the participative group, discussion centred on agency, community, participation in social practices, and the relationship between social and individual dimensions of identity. Within the discursive group a discussion focussing the relationship between identity, language and context arised. Moreover, participants discussed how identity could be te object of research or a conceptual tool for examining other phenomenon. The group discussions also gave participants an opportunity to exchange experiences, questions and concerns about working with theoretical plurality in identity research.

### *Working with empirical data*

In the second session, we moved from mapping theoretical perspectives to working with empirical data. Five of the organisers briefly presented the data and analytical approaches from their own studies. The studies addressed preservice and in-service mathematics teacher identities in relation to social justice, university mathematics, multilingual mathematics teaching, out-of-field teaching and collaborative mathematical problem solving.

Participants then worked in five groups, each using empirical material from one of these studies. Two groups worked with participative perspectives, one with a narrative perspective, and two with discursive perspectives. Each group worked with guiding questions based on the theoretical and analytical approach of the study. For example, the narrative group considered episodes, turning points and connections across a participant's life history, whereas other groups attended to participation, belonging, recognition, valued actions, actors, language and ways of relating to mathematics.

After the group work, participants shared their analyses and discussed what they had noticed through the different perspectives. The session concluded with Skott's (2022) identity triad of agency, situatedness and

structure as another point for discussion. We considered how these dimensions appeared across the different analyses and whether they helped us make connections between the perspectives.

### *Continuing the conversation*

For both participants and organisers, the Working Group provided a starting point for further discussion of the challenges and possibilities that come with different theoretical approaches to identity research. As part of the continuing work of the Identity Network, we have continued our regular meetings following PME49 and are developing a collaborative publication, while connecting with scholars and research groups working on identity across different contexts. We also aim to broaden the network by inviting other researchers working with identity in mathematics education to join these discussions. We thank all participants for contributing their theoretical questions, empirical experiences and reflections to the discussions.

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# DESIGNING PROBLEM SITUATIONS TO FOSTER SENSE MAKING: A TLSOA PERSPECTIVE ON LEARNING TO THINK MATHEMATICALLY

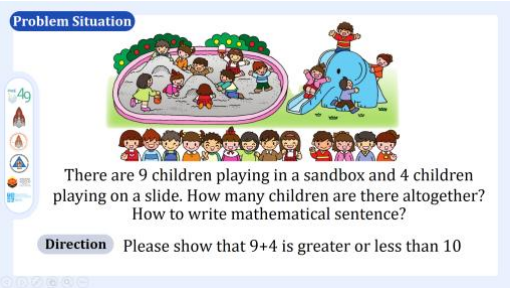
Authors: Nisakorn Boonsena; Chanika Senawongsa; Jitlada Jaikla; Maitree Inprasitha; Narumon Changsri; Ariya Suriyon; Wipaporn Suttiamporn

The PME Working Group on **"Designing Problem Situations to Foster Sense Making: A TLSOA Perspective on Learning to Think Mathematically"** met for the first time at PME-49 in Helsinki, Finland. The Working Group brings together an international community interested in exploring how problem situations can be designed to foster students' sense making and support their development as mathematical thinkers. In particular, the group aims to clarify the notion of sense making in relation to learning to think mathematically; examine how problem situations can structurally promote sense making; explore how the Transformative Lesson Study incorporating the Open Approach (TLSOA) model supports students' engagement in sense making; develop shared design principles; and initiate international research dialogue and collaboration.

**Session 1: From Problem Situations to Students' Ideas**

The first session began with Maitree Inprasitha's introduction to a conceptual framework for analyzing the classroom practices, highlighting the central roles of **students' ideas, problem situations in open class of the TLSOA model**. This provided a common foundation for participants to examine classroom activity by transforming what to teach from traditional conceptual and procedural knowledge to exploring and developing students' ideas. He also proposed that carefully designed problem situation generate students' ideas while making sense of context and condition of problem situation.

Participants then worked with the problem situation **9 + 4** which was how to learn making ten, drawing on their own experiences to anticipate possible students' ideas and strategies. This anticipation was followed by observation of a pre-recorded classroom episode involving first-grade students in Thailand. Participants carefully recorded what they observed in the students' mathematical activity and subsequently compared their anticipated ideas with the actual evidence emerging from the classroom.




*Picture 1 Problem Situation of '9 + 4'*

The discussion highlighted an important issue for the Working Group: **the gap between what adults—including teachers and parents—expect children to think and what children actually think and do when engaging with a problem situation.** This experience demonstrated the importance of observing students' ideas as they emerge in the classroom rather than relying solely on adults' assumptions about how students are likely to reason. It also illustrated how anticipation and observation can work together as important components of teachers' professional learning within TLSOA.

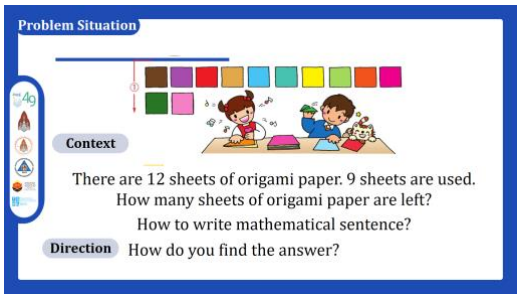
**Session 2: East Meets West—Learning to Think Mathematically**

The second session began with a reflection on **"East Meets West."** Inprasitha traced how researchers from both Western and Eastern traditions have emphasized the importance of students learning to think through problem solving and metacognitive engagement.

From the Western tradition, this trajectory can be seen in Dewey's *How We Think* (1933), Pólya's *How to Solve It* (1945), Schoenfeld's *Mathematical Problem Solving* (1985) and *Learning to Think Mathematically: Problem Solving, Metacognition, and Sense Making in Mathematics* (1992), and Lester's work on metacognition in mathematical problem solving (1989). Schoenfeld's work, in particular, positioned metacognitive monitoring and control as integral to mathematical problem solving and sense making.

A parallel development can be found in the Eastern tradition through Isoda and Katagiri's work on mathematical thinking, Shimada's work on the Open-Ended Approach, and Nohda's study of the Open-Approach Strategy, situated within Japan's long tradition of Lesson Study. From this perspective, the "East Meets West" theme points to a shared concern across traditions: **how classroom experiences can support students in learning to think mathematically by and for themselves.**

Building on this discussion, participants examined four related problem situations: '**13 – 8', '7 – 4', '12 – 9', and '8 – 5'**. Rather than focusing only on obtaining correct answers, participants analyzed the situations through five interconnected TLSOA skills: **understanding the problem situation, understanding students' ideas, anticipation, observation, and reflection**.




*Picture 2 Problem Situation of '12 - 9'*

The discussion was particularly rich when participants considered the **flow and sequence of the lesson** in order to develop mathematical ideas. They explored questions such as: *Which mathematical idea should be addressed first, and why? How can different ideas be connected across the lesson? How can a problem situation support the emergence of students' ideas? What might happen when students are given opportunities to solve a problem in their own ways?* These questions shifted the focus from simply selecting mathematical tasks for teaching to considering how the **design of the problem situation and the sequencing of students' ideas can create opportunities for sense making**.

**Looking Forward**

Across the two sessions, participants began to develop a shared understanding that sense making should not be regarded as an accidental outcome of giving students open-ended problems. Rather, opportunities for sense making need to be **intentionally embedded in the design of problem situations and supported by teachers' anticipation, observation, and reflection** on a cycle of teacher learning such as TLSOA model.

The Working Group therefore moves forward with a shared interest in examining how problem situations can make students' mathematical ideas visible, how teachers can learn to observe and interpret those ideas, and how classroom design can support students in developing mathematical thinking. The discussions at PME-49 provided an important starting point for developing shared design principles and for building an international research dialogue on **learning to think mathematically through problem situations and sense making**.

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# WHERE IS MATHEMATICS DONE? AN EMBODIED PERSPECTIVE ON EYE MOVEMENTS

Authors: Anna Shvarts; Dor Abrahamson; Markku Hannula; Catalina Lomos; Alik Palatnik

The group aimed to cover the following topics: (1) *Theory:* popularizing and developing an embodied perspective on eye-movements as sensory-motor processes within broader body–environment interactions of solving mathematical problems; (2) *Methodology:* reflecting on the limitations and benefits of various ET research designs and working towards a framework for analysing eye movements from an embodied perspective; and (3) *Educational implications*: formulating future directions and research strategies in the embodied approach to ET that would inform mathematics education designs and teacher professionalization.

The group gathered a large audience, of whom about 80% of participants have already used Eye-tracking at least once, and about 40% of the participants were familiar with embodied approaches to mathematics education. As a result, theoretical discussions were the focus of our conversations for quite an extended amount of time: the shift from cognitivist approaches to mathematics thinking and learning, popular in eye-tracking studies, to seeing those processes as essentially embodied requires a significant re-approaching of researchers' personal assumptions. We were very pleased by the active involvement of the young researchers who are still in the search for a theoretical approach that fits their curiosity, and by critical questioning from the side of cognitively oriented senior researchers. We believe that our group provided fruitful insights to both of those groups, and also to us, in clarifying how theoretical paradigms may co-exist in our research field and how the embodied view is not meant to argue for its stronger explanatory power in a positivist picture of science, but comes as a paradigmatic worldview. So we consider our first aim fully fulfilled.

As many methodological questions arose on the first day, we extended the introductory presentation to share with the participants possible methodological directions and know-how in working with eye-tracking data from embodied experience. The questions of manual coding and aligning the views from different cameras are at the core of technical limitations. At the same time, scrupulous analysis of the small fragments of multimodal interaction enriched by eye-tracking turned out to be very insightful for the participants. This raised questions about the types of inquiry that analyzing eye movements of embodied interactions can address. We could distinguish four layers of embodied involvement; each of them would allow for less quantitative and richer multimodal data: (1) single-person screen-based eye-tracking; (2) single-person head-mounted eye-tracking supported by audio and video recording; (3) dual eye-tracking on an activity on a common surface; (4) multiple people multimodal collaboration in space. While (1) allows for fully automated quantitative analysis, (2) and (3) can allow for some automation in some cases, and finally (4) still requires extensive manual coding and is mostly done with micro-ethnographic techniques.

Finally, the third aim of our group – design and professionalization consequences – was addressed in a limited way: through some questions and plenary discussion, rather than systematic group work. We can conclude that we and our audience were not yet ready to make a solid step toward the educational applications of embodied research with eye-tracking. At the same time, the theoretical view of mathematics as *being done in interaction with the environment* can be strongly corroborated by data from eye movements and creates a solid space for establishing educational implications in the future.

An emergent outcome of the WG, which holds promise for its re-instantiation in future PME gatherings, is the establishment, including a list of names and email accounts, of a core group of researchers, from a wide span of professional experience, with interest in continuing the conversation.

# YOUTH'S VIEW ON MATHEMATICS FOR HUMAN RIGHTS

Authors: Yasmine Abtahi; Trine Foyn; Matijas Loeb; Richard Barwell; Suela Kacerja; Beth Herbel-Eisenmann; Kjellrun Hiis Hauge; Lisa Steffensen

Our working group brought together researchers from different international contexts to explore the role of mathematics education in addressing human rights, democracy, and dignity. Across the two sessions, participants reflected on students' voices, the opportunities and challenges of integrating human rights into mathematics classrooms, and the responsibilities of educators in our increasingly polarized societies. A central theme in our discussion was the importance of listening to students. We noted that students are often eager to engage with human rights issues and are capable of connecting these issues to mathematics.

As an example, we shared artefacts creating by secondary school students as part of the Values in Mathematics Teacher Education project. The students explored the relationship between mathematics and human rights values. The artefacts showed that they could see numbers as representing lived realities rather than merely abstract quantities. These artefacts were powerful expressions of students' views and concerns.

Through discussion prompted by the student-created artefacts, the working group participants considered how mathematics can create meaningful opportunities to examine issues such as inequality, life expectancy, environmental disasters, and social justice. In addition, the participants noted that the mathematical content must remain visible.

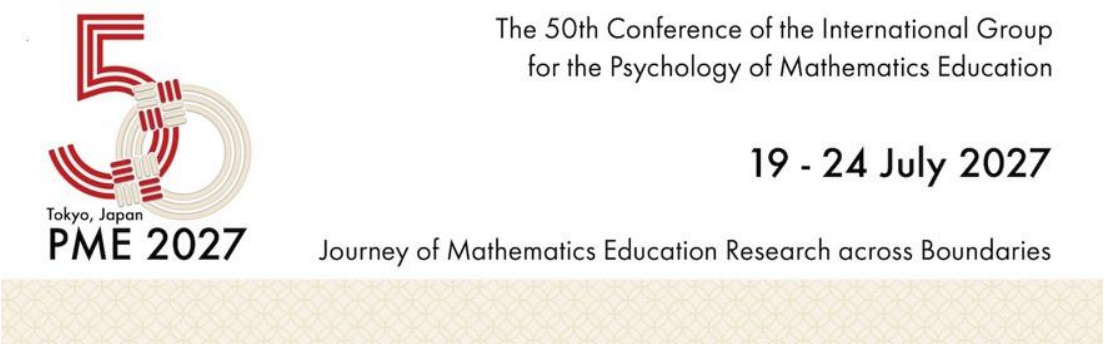
The discussions also explored the risks associated with addressing controversial issues. Participants acknowledged that teachers may face resistance from parents, communities, institutions, or governments. Experiences from countries such as Brazil, South Africa, Iran, Germany, and the United States highlighted how educators and students can face significant consequences for speaking about political or social concerns. Several participants stressed the need for teacher education programs to prepare future teachers to address and explore these risks thoughtfully and ethically.

Another important theme was the relationship between education and democracy. Participants emphasized the educational value of helping students engage with multiple perspectives where conflict were viewed not as problems but as an important part of learning. Participants also highlighted that opportunities to speak openly are shaped by context and privilege. We reflected on how poverty, political oppression, social vulnerability, and institutional power affect who can participate in discussions. Hence, silence should not be interpreted as complicity.

We concluded that while mathematics classroom discussions may not immediately lead to societal change, they can contribute to the development of critical human beings. Given the opportunity, young people have much to say about mathematics in relation to human rights. Overall, the working group reaffirmed the power of mathematics education to support human rights, democracy, and dignity, while at the same time recognizing the challenges, risks, and complexities involved in this work.

# Looking ahead to PME50 in Japan

*Update from the PME50 organizing team*




Yoshinori Shimizu and Kotaro Komatsu (Co-chairs of PME50; University of Tsukuba)





We are pleased to host the 50th conference of PME (PME50) in Tokyo, Japan, from 19 to 24 July 2027. We look forward to welcoming participants from around the world to this special milestone conference and hope that the event will bring the community together for scholarly exchange and collaboration.

The theme of the conference is “Journey of Mathematics Education Research across Boundaries”. We intentionally selected this theme to celebrate PME’s 50th anniversary conference and to encourage all the participants to reflect on the development of mathematics education research in general, and of PME in particular, over the past half-century through interactions across various boundaries, including those between cultures, disciplines, and research and practice. We also hope that PME50 will provide an opportunity for participants to envision the future of mathematics education research and explore its emerging challenges and possibilities.

### Preparing your contribution

PME session types mainly consist of personal presentations and group activities. Personal presentations include Research Reports, Colloquia, Publication Reports, Oral Communications, and Poster Presentations, while group activities include Research Forums, Working Groups, and Seminars. Further information about each submission type is available at: https://www.igpme.org/annual-conference/session-types/. The deadline for submission is 15 January or 1 March 2027, depending on the type of contribution.

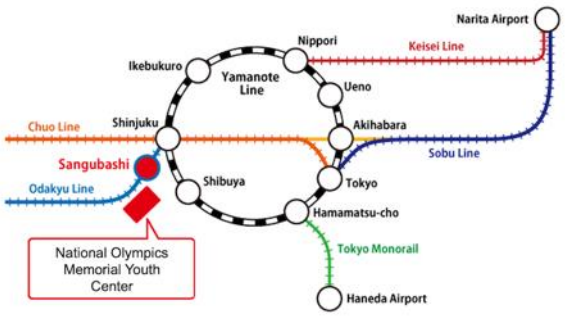
All submissions must use the PME50 template available on the PME50 website. Proposals should be submitted through the PME50 ConfTool online system (available from early December 2026). Submission through ConfTool is only possible if the presenting/corresponding author has registered in ConfTool and paid the non-refundable conference deposit (i.e., the pre-registration fee). Please note that Research Forums have a different submission deadline and procedure (e.g., initial submission by 15 December 2026 via email).

## Planning your participation

Pre-registration and full registration for PME50 will begin in early December 2026 and March/April 2027, respectively, and both processes will be conducted online through ConfTool. We will use PayPal for payment, so participants who do not yet have a PayPal account are kindly requested to create one in advance.

The conference venue is National Olympics Memorial Youth Center, located in central Tokyo. The venue is a 7-minute walk from Sangubashi Station (Odakyu Line from Shinjuku Station). A wide range of hotels is available in Shinjuku, and participants may also choose to stay in other areas of Tokyo, as the city's public transportation network is extensive and convenient. Participants are encouraged to download the Welcome Suica Mobile App (available for iPhone users) or purchase a Welcome Suica IC card at the airport for use on public transportation (e.g., trains, metros, and buses).






Affordable accommodation (very simple/basic rooms!) will also be available at the conference venue. Information regarding reservations and payment procedures will be announced on the conference website in late March or April 2027.

The conference will also organise the Early Researchers' Day (ERD) programme on site on 18 and 19 July 2027. Early career researchers are welcome to participate in it.

## Where to find updates

Please visit the PME50 website: https://pme50-tokyo.jp

We look forward to seeing you at PME50!

INTERNATIONAL GROUP FOR THE
PSYCHOLOGY OF MATHEMATICS EDUCATION

# Free online webinars before PME50

*PME Early Researchers' Series 2026/2027 | November–June*

PME's free online webinars offer practical guidance on developing and submitting conference contributions and on navigating the Annual Conference. The series is especially valuable for newcomers and welcomes participants at every stage of their PME journey.

## Session 1 · Getting Started with PME

**Overview and Pre-submission Support**

Speaker: Alf Coles, University of Bristol

**Thursday, 5 November 2026 · 09:00–10:00 UTC**

Local times: Vancouver 02:00–03:00 · Santiago de Chile 06:00–07:00 · Brussels 10:00–11:00
Johannesburg 11:00–12:00 · Bangkok 16:00–17:00 · Tokyo 18:00–19:00 · Auckland 22:00–23:00

Register for Session 1: https://bit.ly/4zGUAyc

Use the registration link or scan the QR code.

## Meet the speaker



Alf Coles is Professor of Mathematics Education in the School of Education at the University of Bristol, UK. His research interests include teacher development, the use of video in professional learning, and listening in mathematics classrooms. He also studies early number, classroom creativity, and metacognition. His recent work explores mathematics teacher education and its responsibilities for sustainable futures. He also serves as PME's Pre-submission Support Coordinator, supporting researchers in preparing their work for submission to PME conferences.

## Meet the organizers

### Ofer Marmur



Ofer Marmur is a Senior Lecturer in Mathematics Education at the University of Auckland, New Zealand. His research explores the cognitive, emotional, and social dimensions of mathematics learning, gestures in mathematical thinking, and teachers' mathematical and pedagogical knowledge. He joined the PME Board in 2024.

### Yusuke Shinno



Yusuke Shinno is a Professor at Hiroshima University, Japan. His research includes mathematical proof, international comparisons of classroom argumentation, task design, and teacher education. He joined the PME Board in 2025.

## Keep up with the series

Further session dates, speakers, and registration details will be announced through the PME Mailing List, which is open to members and non-members. Join the PME Mailing List

PME
INTERNATIONAL GROUP FOR THE
PSYCHOLOGY OF MATHEMATICS EDUCATION

# Host a future PME conference

*Could your community welcome PME?*

Hosting a PME conference is an opportunity to bring the international mathematics education research community to your institution, share ideas and build lasting collaborations. We are particularly keen to hear from colleagues interested in hosting PME53 in 2030.

### Start early

**Bids should be prepared at least two years in advance. For PME53 in 2030, we expect a bid in December 2027.** Please contact us well before then so that there is time to explore your ideas, discuss responsibilities, and develop a proposal.

### What hosting involves

A successful bid brings together a committed local organizing team, institutional support, and a realistic financial plan. The Conference Chair and several members of the organizing committee should have attended a PME conference, bringing an understanding of its scientific aims and traditions.

Hosts normally offer a university or college venue with suitable meeting spaces, affordable accommodation, and accessible travel arrangements, including visa support.

Hosts work with PME on the scientific program and manage the conference arrangements, budget, proceedings and social program. We will share detailed guidance when you contact us.

### Interested in exploring the possibility

You do not need a completed proposal to start a conversation. If your institution or research community might be interested, please contact both:

**communications@igpme.org** and cc **info@igpme.org**

We can provide the hosting guidelines, explain the bidding process, and discuss your questions. An early conversation is the first step towards shaping a proposal to welcome PME.



PME50



PME51



PME52



PME53