EMBODIED MATHEMATICAL IMAGINATION AND COGNITION (EMIC) WORKING GROUP

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The central aim of the EMIC Working Group is to connect, engage, and inspire colleagues in this growing community of discourse around theoretical, technological, and methodological developments for advancing the study of embodied cognition for mathematics education. This year, our fifth at PME-NA, we also will convene on Day 3 with the WG on Mathematical Play. Our community of scholars will use these sessions to continue to broaden the range of activities, practices, and emerging technologies that contribute to mathematics teaching and learning as well as to research on these phenomena.

Keywords: Cognition; Embodiment and Gesture; Informal Education; Learning Theory

Empirical, theoretical, and methodological developments in embodied cognition and gesture studies support the continuation of the regularly held Embodied Mathematical Imagination and Cognition (EMIC) Working Group for PME-NA. The central aim of EMIC is to attract, engage, and inspire colleagues in a growing community of discourse for advancing the study of embodied cognition for mathematics education, including mathematical reasoning, instruction, assessment, technology design, and learning in and outside of formal settings.

Views of learning as embodied experiences have grown from several developments in philosophy, psychology, anthropology, education, and the learning sciences that frame human communication as multimodal interaction, and human thinking as multimodal simulation of sensory-motor activity (e.g., Lave, 1988; Nathan, 2014; Wilson, 2002). Four ideas exemplify the plurality of ways EMIC is relevant for the study of mathematical understanding: (1) *Grounding abstractions in perceptuo-motor activity as an alternative to amodal symbol systems;* (2) *Cognition emerges from perceptually guided action*; (3) *Mathematics learning is always affective*, never detached from body-based feelings and interpretations; (4) *Mathematical ideas are conveyed via multimodal forms of communication, e.g., gestures, drawing, and objects.*

The interplay of multiple perspectives is vital for the study of embodied mathematical cognition to flourish. While there is significant convergence of theoretical, technological, and methodological developments in embodied cognition, there remain questions to be addressed through formulating and applying experimental design principles. We aim to: (1) synthesize the work of leading scholars into a theory of EMIC; (2) identify and negotiate focal ontologies and parameters that capture our theoretical, methodological, and technological variability; (3) curate and disseminate evidence-based design principles to enhance mathematics education and broaden participation in STEM fields; and (4) articulate a research agenda in embodied design.

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Past Achievements, Current Organizers, and the Future of EMIC

This is the 5th year of the EMIC WG. Several activities and website have emerged to connect scholars and provide resources, https://www.embodiedmathematics.com. Two NSF workshops for researchers and instructors grew from this: "The Future of Embodied Design for Mathematical Imagination and Cognition" (May 20-22, 2019); and "EMIC: Professional Development for Undergraduate Mathematics Instructors" (June, 2021). An edited book is planned for the "Research in Mathematics Education" Series and an article is under review for *Frontiers in Education* Research Topic: "Futures of STEM Education."

As the WG matures, we are broadening the set of organizers to represent a range of institutions, perspectives, and applications. This enriches the WG experience and the long-term viability of the community. The organizers not included in the authorship list are listed here: Candace Walkington, Southern Methodist University; Carmen J. Petrick Smith, University of Vermont; Hortensia Soto, University of Northern Colorado; Ivon Arroyo, University of Massachusetts-Amherst; and Martha W. Alibali, University of Wisconsin-Madison.

EMIC 2020: Embodiment in Mathematics for Inclusion

Embodiment is an effective way to promote inclusive mathematics education research and practices. This year we will explore how embodied mathematics can bridge cultural divides and raise awareness of inclusion for those with different physical and perceptual abilities (Abrahamson et al., 2019). To demonstrate growth and relevance, we will also join the Mathematical Play WG on Day 3 to integrate EMIC and Play research and practice.

On Day 1 we will discuss the goals for PME-NA 2020 to bridge divides that arise across those with different physical and perceptual abilities. As is customary with EMIC, we will anchor this to mathematical activities (e.g., making human-scale polyhedra). For a portion of the time, participants will collaborate without sight, to identify how our bodies offer effective ways to engage. This will invite us to identify principles of inclusive pedagogy and activity design. This will be connected to the 4 EMIC themes: Grounding, emergence, affect, and multimodality.

On Day 2, we will explore mathematical collaboration when participants cannot rely on a shared language. In order to challenge the norms of mathematical activities (e.g., Bagh Chal from Nepal), we will include puzzles and games that are foreign to majority cultures.

On Day 3, EMIC will meet with the Math Play WG to consider overlapping interests and questions. The organizers of both WGs led a joint conference proposal that is currently under review, and Day 3 will be our first overt synthesis of the two bodies of work. The session will include small activity groups with Math Play participants who want to think about their work as embodied and EMIC participants who want to think of their work as math play opportunities. After, we will review Days 1 and 2, we consider how our themes overlap, ways to enhance future PMENA conferences, as well as the broader ways that embodiment, imaginative thinking, and play can be used to promote inclusivity. We will conclude by discussing continued engagement and dissemination opportunities available with both the EMIC and Math Play communities.

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Figure 1: A small selection of embodied activities created by EMIC organizers and experienced by EMIC participants. Clockwise from top left: experiencing geometric transformations, acting out geometry conjectures, constructing icosahedra first as small, then at human scale, and enacting topological relations.