# An introduction to TWG23: Implementation of research findings in mathematics education

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## Introduction

This introduction outlines the seventeen contributions presented in the TWG23 at CERME13. The content of the contributions gravitates around five pivotal themes: large-scale implementations, theoretical underpinnings, problem-solving research, computational thinking paradigms, and practical teaching model implementations. Furthermore, two thematic discussions took place, emphasizing the significance of theoretical grounding in implementation research and the life cycle of educational innovations.

## Contributions to the TWG23 at CERME13

The TWG23 at CERME13 was led by Mario Sánchez Aguilar, Linda Marie Ahl, Boris Koichu and Morten Misfeldt. The TWG23 received 17 papers addressing different aspects of implementation research in mathematics education. The authors of the contributions came from Denmark, France, Israel, Italy, Mexico, Sweden, and the United Kingdom. The contributions were organized into thematic categories:

- Reflections on large-scale implementations and scale issues.
- Theoretical reflections on implementation.
- Problem-solving and implementation research.
- Computational thinking and implementation research.
- Implementation of teaching models and approaches.

### Reflections on large-scale implementations and scale issues

The first thematic category, “Reflections on large-scale implementations and scale issues,” included various studies. One segment of these contributions addresses the evaluation and dynamics of large-scale innovation implementation. For instance, Iresha Gayani Ratnayake and colleagues delved into the characteristics that determined the innovation’s impact on target groups, particularly comparing the projects TRIUMPHS (implemented in the United States) and Boost for Mathematics (implemented in Sweden). They found that TRIUMPHS’ relative success, compared with the BM, may rest on voluntary participation, flexibility in innovation enactment in terms of fidelity and adaptation, and a scaling plan resting on the teachers seeking out the innovation rather than the innovation being mandatory for the teachers. Another contribution was by Michèle Artigue and

Blandine Masselin, who, drawing on the systemic and ecological approach offered by the anthropological theory of the didactic, charted the evolving dynamics of implementing adapted Lesson Studies in France and highlighted the emergence of a hybrid object that intermingled the Lesson Studies and IREM cultures of teacher professional development.

A different strain within this category centers on investigating factors influencing the implementation of curriculum reforms and teaching models. A systematic literature review by Linda Marie Ahl and collaborators pinpointed that curriculum change is deeply intertwined with shifts in teachers' concerns, beliefs, views, and images about the nature of mathematics teaching and learning. They also find that the level of support from the school and the innovations' adaption to context are decisive for the implementation outcome. In turn, the work by Tuula Koljonen, Ola Helenius, and Linda Marie Ahl focused on the large-scale implementation of the teaching model "Thinking reasoning and reckoning." By analyzing video recordings of a third-grade teacher's innovation enactment of a teaching cycle, these authors shed light on deviations from implementation program determinants within the large-scale project.

Another dimension of this thematic category is the dialogue between implementation research and professional development. This dimension is captured in the study by Johan Prytz, Linda Marie Ahl, and Uffe Thomas Jankvist, who grappled with the complexities of replicating the Boost for Mathematics project even with existing studies measuring its effects. They argue that replication requires better knowledge about the innovations and suggest further research. Lastly, the study by Mario Sánchez Aguilar and collaborators explored the conceptions of large-scale and small-scale projects among educational researchers. This research underlined researchers' emphasis on quantitative aspects such as the number of involved teachers, schools, or districts reached by an implemented innovation or reform.

**Theoretical reflections on implementation**

The second thematic category, "Theoretical reflections on implementation," integrates two main contributions. The first strand of these contributions investigates theoretical models and frameworks addressing the nuances of implementation research in mathematics education. For instance, Jennie Golding uses the lens of education policy heterarchical social network approaches to shed light on the dynamics of stakeholder communication and influence in curriculum implementation. Mark Boylan, on the other hand, propounds a holistic theory of change model that eschews traditional linear logic models. Instead, Boylan's model accentuates the complexity of innovation, viewing change as an ongoing process and challenging conventional interpretations of the theory of change.

Other contributions within this category explore innovative concepts and heuristics in implementation. A case in point is the research by Cecilie Carlsen Bach and collaborators, who introduce the concept of "humble implementation heuristics." Rooted in the principles of design-based research and drawing from the meta-practice of networking of theories, this research offers fresh perspectives on the implementation processes of innovations, providing concrete examples from a specific case study. This unique blend of theoretical investigations and innovative concepts enhances our understanding of the multifaceted nature of implementation research in mathematics education.

**Problem-solving and implementation research**

Another thematic category is "Problem-solving and implementation research." This category encompasses two lines of contributions. One line primarily targets the intricate interplay between problem-solving and its implementation in educational settings. For instance, Jason Cooper and Esther Gruenhut's research delves into the challenges and opportunities of implementing problem-solving through research-practice partnerships. They emphasize the vital roles of teachers' reflective questionnaires as tools for investigating and enhancing the problem-solving implementation process. Boris Koichu, Aamer Badarneh, and Menucha Farber further the discourse by evaluating the merits of co-learning agreements in bolstering problem-solving in middle schools. Their work underscores the differential learnings of researchers and teachers from the same data, highlighting the richness this divergence brings to the implementation process.

A second line of contributions investigates the mechanics of research-based innovations and their relevance in practical settings. David Nordqvist, Linda Marie Ahl, and Ola Helenius present a case on the effectiveness and scalability of an innovative teaching model designed to improve students' formal written communication of a solution to a mathematical problem. They accentuate the significance of diverse influential factors when contemplating a broader implementation scope. Furthermore, the work by Ola Helenius and colleagues delves into the criticality of an explicit theory of change in implementation research. Through their analytical lens, they unravel potential determinants that retrospectively decode the efficacy mechanisms of an innovation program, further enriching the discourse on problem-solving and its research-driven implementation in educational environments.

**Computational thinking and implementation research**

The fourth thematic category, "Computational thinking and implementation research," focuses on the synergy between programming and computational thinking (PCT) and mathematics. This synergy is exemplified through the work of Morten Misfeldt and colleagues. Their work explores the lived experiences of three educators attempting to blend PCT with mathematics in their teaching. The research underscores the inherent challenges these educators encounter while attempting to integrate PCT seamlessly into traditional mathematics curricula, emphasizing the necessity for support and resources for effective implementation.

Another work included in this category is the one by Andreas Lindenskov Tamborg and Liv Nøhr. This investigation focuses on the practicalities and actualities of implementing computational thinking (CT) within mathematics classrooms, shedding light on the prevalence of CT teaching among Danish mathematics teachers. Their findings, which deviate significantly from prior research, suggest that most of the surveyed teachers are already infusing CT into a broad spectrum of mathematical domains, even without a formal curriculum directive. These findings indicate a need for a future implementation strategy for CT in Danish compulsory school mathematics, ensuring the alignment of CT practices with foundational mathematical principles.

**Implementation of teaching models and approaches**

Finally, the thematic category "Implementation of teaching models and approaches" includes two studies. Firstly, Julia Tsygan, Ola Helenius, and Linda Marie Ahl present an empirical work on a teaching model centered around fostering students' competence in producing formal written mathematical communications. Using the International Baccalaureate program as a backdrop, they scrutinize the potential transferability of these communication competencies to a broader context, such as thesis writing. They conclude that the work with formal mathematical communication during specific mathematics lessons has transfer effects on the general handling of students' written mathematical communication.

In turn, Alessandra Boscolo ventures into the enactive-embodied perspective of mathematics education and explores its implementation across different schooling levels in Italy. Her insights, particularly from teacher surveys and interviews, underline critical challenges such as resource constraints, time pressures, and lack of confidence, painting a vivid picture of the ground realities of bringing innovative teaching methods to the classroom. This research underscores the importance of preparing teachers in terms of resources and pedagogical understanding for successfully assimilating new educational paradigms into existing curricula.

## Thematic discussions

The TWG23 program included two thematic discussions: (1) "What is the role of theory in implementation research?" and (2) "The life cycle of an innovation". The first thematic discussion pointed out how the theoretical landscape in implementation research tends to be layered, encompassing both foreground- and background theories. While foreground theories provide detailed explanations for specific phenomena under study, background theories offer broader contextual understanding.

Inspired by the institutional and ecological perspective offered by the Anthropological Theory of the Didactic, during the second thematic discussion, we explored how introducing an innovation within an educational system can be likened to an ecological disruption where the innovation is either adopted or rejected. Often, the fate of an innovation depends on various factors, including its compatibility with existing systems, perceived benefits, and the willingness of individuals or organizations to embrace change. This conceptualization illustrates how innovations may encounter initial resistance but eventually gain acceptance when the conditions for change are suitable. Overall, the discussion converged to the conclusion that implementation-related phenomena require not only "borrowing" theoretical constructs from the existing theories but purposeful conceptualization work that would account for the complexity of the phenomena in ways useful for practice.

At CERME14 in Bozen-Bolzano, Italy, the TWG23 will further explore the multifaceted area of implementation research in mathematics education. Building on the discussions and findings from CERME13, the group aims to dive deeper into the emerging themes and challenges.