Introduction to the NOMAD 2025 special issue on the teaching and learning of mathematical modelling in the Nordic contexts

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This paper introduces the NOMAD 2025 special issue, which focuses on the teaching and learning of mathematical modelling in the Nordic contexts. In order to situate and contextualise the contributions of this special issue, the paper begins with a brief overview of Nordic researchers' activities and roles within the broader international research community focused on mathematical modelling. The paper then provides a brief overview of previous mathematical modelling research published in NOMAD since 1993, before proceeding to discuss the contributions of this special issue. In addition to providing a brief summary of each paper, we analyse them in relation to their adopted theoretical frameworks, methodological approaches, and analytical strategies. The paper concludes with a discussion and outlook for future research avenues.

Mathematics education is as old as civilization itself (Jones, 1968), and ancient artefacts provide evidence of mathematical tasks that were used for educational purposes. A famous example is the Rhind Mathematical Papyrus which collects a number of arithmetic and algebraic problems. Indeed, Dansei (2016) writes that "[t]he [Rhind] *Papyrus* is thought to be a math textbook, as can be surmised by the fact that its content is highly pedagogical and it is laid out very much like a modern-day math textbook" (p. 5, italics in original). While these early artefacts reveal mathematics as a structured discipline, they also underscore a recurring theme in the mathematics educational history: the tension between abstract theory and practical utility. Across centuries, educational reforms have repeatedly sought to make mathematics teaching more "useful," whether

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for commerce, engineering, or scientific inquiry (Stanic & Kilpatrick, 1989). Today, this emphasis on usefulness in mathematics education finds one of its most comprehensive expressions in *mathematical modelling and applications* (or just mathematical modelling for short); that is in approaches that position mathematics as a tool for interpreting, representing, and solving real-world problems. Broadly understood, mathematical modelling and applications involve constructing and refining mathematical representations of systems or phenomena from diverse contexts, such as science, technology, society, and everyday life, to achieve a given objective (Niss & Blum, 2020).

Research on mathematical modelling in education has grown significantly over the past decades, shaping both theory and classroom practice (Blum, 2015). The roots of the research field trace back to the influential work of Freudenthal and Pollak in the late 1960s (e.g., Freudenthal (1968) and Pollak (1968)), who emphasized teaching mathematics as a useful tool for real-world problem solving. This early motivation and discussion led to the formation of the *International Community of Teachers of Mathematical Modelling and Applications* (ICTMA) in 1983 (Houston et al., 2009), as well as the subsequent establishment of dedicated working groups within major mathematics education conferences such as ICME[1] and CERME[2]. To put the contributions in the special issue into context with respect to this research field, this introductory paper first gives a brief overview of the activities and role researchers from the Nordic countries have been engaged in and played in the larger research community focusing on mathematical modelling, and then summarises and analyses the previous papers on modelling previously published in NOMAD.

International Community of Teachers of Mathematical Modelling and Applications (ICTMA)

ICTMA is an international community that, since its inception in 1983, has organized regular conferences and published proceedings to promote the teaching and learning of mathematical modelling and applications, connecting educators and applied mathematicians worldwide. Over the years, ICTMA has established itself as a central forum for research in this domain. During its first 25 years, the community evolved from addressing primarily higher education needs to influencing curricula, research, and practice across all educational levels, with a sustained emphasis on real-world problem solving, collaboration, and innovation (Houston et al., 2009). This broad scope continues to characterize ICTMA today.

To better understand the Nordic contribution to this international arena, we examined authorship patterns across all 22 ICTMA proceedings published to date (from ICTMA 1 to ICTMA 21 with two published proceedings from ICTMA 2). Nordic researchers have participated as authors or co-authors to a varying extent as can be seen in figure 1 showing the percentage of ICTMA proceedings chapters featuring Nordic researchers' contributions.

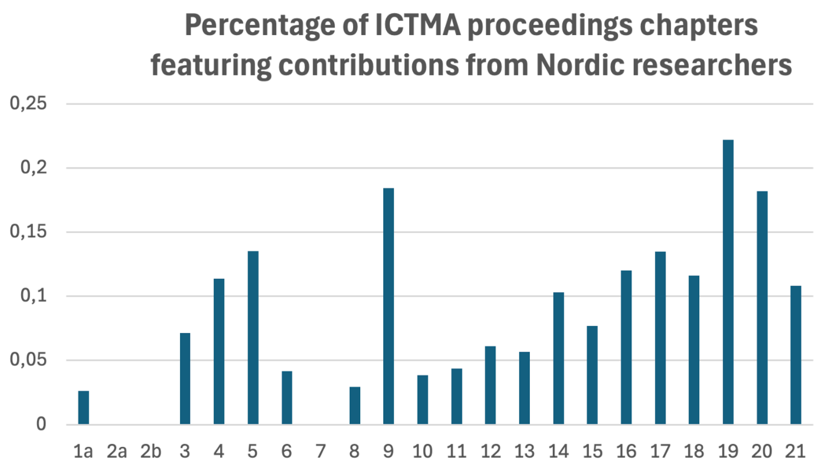

Figure 1. *Percentage of ICTMA proceedings chapters featuring contributions from Nordic researchers*

In total, Nordic researchers were found to be involved in 88 chapters out of 930 (approximately 9% of all chapters), averaging 4 chapters per ICTMA proceedings, with no contribution at ICTMA 1b, 2 and 7. The Nordic participation has not been evenly distributed, as can be seen in Figure 1. Several conferences (e.g., ICTMA 2 and 7) had no Nordic-authored chapters, indicating periods of limited engagement, at least with respect to contributing with written chapters. Since ICTMA 16, Nordic participation has constituted over 10% of the chapters of the proceedings, with as high as 22% of the chapters in the proceedings from ICTMA 19 in Hong Kong. Overall, this trend suggests a growing Nordic presence in the ICTMA community over time, albeit with notable fluctuations. Notably, Nordic researchers have on numerous occasions given plenary lectures or participated in plenary panels at the ICTMA conferences. In addition, two of the ICTMA conferences between 1983 and

2025 have been hosted in the Nordic countries, namely ICTMA 4 in 1989 in Roskilde (Denmark) and ICTMA 22 in 2025 in Linköping (Sweden).

Conference of the European Society for Research in Mathematics Education (CERME)

The first Topic Working Group (TWG) on *Modelling and Applications* was organized at the CERME4 conference and has since remained an active TWG across the last 11 CERME conferences. Barquero (2023) describes the development of the TWG in three phases: an early phase (CERME4–7), characterised by identifying and mapping diverse approaches and the emergence of frameworks (e.g., modelling cycle, RME, ATD, CHAT, MMP); a middle phase (CERME8–10), marked by an increased focus on modelling cycles, task authenticity, and teacher education; and a recent phase (CERME11–13), which has seen a surge in submissions and greater emphasis on teacher education and societal relevance. Throughout this developmental process of the TWG spanning the 11 congresses, 40 of the 230 papers presented (17 %) and 3 out of 20 posters (15 %) have been authored by researchers from the Nordic countries. Regarding the TWG's organization, Nordic representatives have been part of the TWG leader team at all congresses except one. Of the total 52 TWG team leader positions over the years, 14 (27 %) have been held by Nordic researchers, and in four out of the 11 organising teams (36 %), a Nordic researcher has served as the TWG team leader.

Prior research on modelling in NOMAD (1993–2025)

Given the significant role and contributions of mathematics education researchers to both the international research community (e.g., ICTMA) and the more Eurocentric research community (e.g., CERME), it is not surprising that a review of NOMAD publications from 1993 to 2025 reveals several papers focusing on or using modelling. In line with Julie and Mudaly's (2007) conceptualisation, two broad categories of modelling papers can be identified: those that treat modelling as a goal in its own right and those that use modelling as a vehicle for learning other content. To summarize the previous NOMAD papers on modelling, a search of the NOMAD database was conducted using two inclusion criteria: (i) the paper must explicitly discuss or use modelling in one of the two ways described by Julie and Mudaly (2007), and (ii) it must include at least three references to the international discussion on modelling and applications. Based on these criteria, a total of 11 papers were identified as focusing on modelling as a goal in its own right, and 8 papers as using modelling as a vehicle for learning. Of these 19 papers, four (three from the first category and one from the second) were authored by non-Nordic researchers. Nevertheless, all 19 papers are briefly summarised in the next two subsections.

Modelling as a goal in its own right

In the category of papers that focus on modelling as a learning goal in its own right, already in NOMAD's second year, Niss (1994, *Challenges to the preparation of teachers of mathematics*) argued that mathematical modelling should be an integral part of teachers' knowledge because it demonstrates how mathematics connects to real-world contexts and applications. Niss emphasised that teacher education often neglects modelling, which limits teachers' ability to present mathematics as a dynamic, relevant, and creative discipline. Kadijevich (1999, *What may be neglected by an application-centred approach to mathematics education*?) also discussed arguments for implementing modelling in mathematics education, while pointing out the risks and limitations of adopting an overly narrow perspective on modelling. One broad line of research on teaching and learning modelling focuses on specific competencies in relation to modelling, and in this context Skov Hansen et al. (1999, *Modelkompetencer*) introduced a framework of nine model competencies (such as structuring, mathematising, validating, and reflecting) that describe the skills involved in mathematical modelling, and argued that these competencies provide a nuanced understanding of modelling processes and can guide teaching, learning, and analysis of modelling activities in mathematics education. Another of the broader perspectives on modelling is the so-called Models and Modeling Perspective (MMP; cf. Lesh & Doerr, 2003). In a theoretically and historically oriented paper, Mousoulides et al. (2007, *From problem solving to modeling – the emergence of models and modeling perspectives*) synthesised 25 years of U.S.-centred research, tracing how the MMP evolved from a traditional problem-solving research perspective into a distinct research domain.

The MMP is just one of several theoretical perspectives on modelling (cf. Kaiser & Sriraman, 2006). In the context of university mathematics courses in Norway, Treffert-Thomas et al. (2017, *Mathematics lecturers' views on the teaching of mathematical modelling*) investigated lecturers' views and use of mathematical modelling. Their study revealed that multiple perspectives were held among respondents, but the so-called realistic perspective (cf. Kaiser & Sriraman, 2006) was by far the most dominant. Kacerja et al. (2017, *Stimulating critical mathematical discussions in teacher education: use of indices such as the BMI as entry points*) using Skovsmose's (1992; 1994) modelling-related concept of mathemacy and source criticism as a framework, explored how practising teachers reflect on the Body Mass Index (BMI) in a numeracy class. Kacerja et al. highlighted how teachers critically examined the BMI formula, its societal use, and its implications, revealing the potential of such discussions to deepen awareness of real-world applications of mathematics and related issues.

Both Frejd (2013, *An analysis of mathematical modelling in Swedish textbooks in upper secondary school*) and Berget (2022, *Mathematical modelling in textbook tasks and national examination in Norwegian upper secondary school*) have analysed aspects of modelling at the upper secondary level, focusing on textbook tasks, instructions of modelling, and national examinations. More general, Blomhøj (1993, *Modellerings betydning for tilegnelsen af matematiske begreber*) illustrated and argued that mathematical modelling tasks, such as those involving dynamic systems and difference equations, foster conceptual understanding by requiring students to build, analyse, and critique models within realistic contexts. This resonates with Stillman's (1998, *Engagement with task context of applications tasks: student performance and teacher beliefs*) finding that students value realism and clear objectives as facilitators of engagement, and that integrating mathematics with context is essential for avoiding disengagement. Both Blomhøj's and Stillman's studies highlighted that authentic, well-integrated contexts in modelling tasks are key to promoting engagement and deeper mathematical learning. Along similar lines, Pongsakdi et al. (2016, *Improving word problem performance in elementary school students by enriching word problems used in mathematics teaching*) showed that enriching word problems to include modelling elements significantly improves students' problem-solving skills. This reinforced the shared view that well-designed, context-rich tasks are essential for developing modelling competencies and fostering deeper mathematical understanding.

Modelling as a vehicle for learning other content

Also in the category of papers that can be considered to use modelling as a vehicle for learning other content (cf. Julie & Mudaly, 2007), a range of approaches can be observed. For example, in the context of statistics education, both Prodromou (2013, *A modelling approach to probability – analysing students' conceptual structures*) and Blomberg (2025, *Preparing prospective primary school teachers in teaching informal statistical inference*) used a modelling approach to frame and design their research interventions albeit not putting modelling in the forefront. A similar usage of modelling to that of Prodromou's (2013) and Blomberg's (2025), but more narrowly applied, was found in Hähkiöniemi et al. (2013, *Teacher-assisted open problem solving*), who employed open modelling tasks to study 9th-grade students interpreting real-world situations, making assumptions, and constructing mathematical representations using GeoGebra. This approach to modelling was also evident in Nortvedt (2010, *Understanding and solving multistep arithmetic word problems*) and Riesbeck (2006, *Det hänger på decimalen! Om hur vi formar och bygger meningsmönster i vår omvärld*). Nortvedt (2010), focusing on the construction of adequate so-called accurate situation models (cf. Leiss et al., 2010) in the context of solving multistep arithmetic word problems, treated modelling as a cognitive process of translating text into mathematical representations. The study showed that many students struggle with the construction step involved in modelling, and that the misrepresentation of relationships between quantities, alongside calculation errors, highlight that success depends on integrating reading comprehension with modelling and numerical skills. Riesbeck (2006), on the other hand, demonstrated that students' understanding of decimals depends on how they connect everyday contexts to mathematical representations and used modelling to bridge the two. By engaging students in constructing tools like number lines and using dialogue, modelling supported the iterative process of linking informal experiences with formal mathematical structures, enabling deeper conceptual understanding.

Several contributions highlight modelling as a powerful tool for teacher education and professional development. Jankvist and Niss (2020, *Fostering an intimate interplay between research and practice: Danish "maths counsellors" for upper secondary school*) used modelling to bridge research and classroom practice in an in-service teacher programme, making research findings more relevant and actionable for teachers. Similarly, Jankvist et al. (2013, *Preparing future teachers for interdisciplinarity – designing and implementing a course for pre-service upper secondary teachers*) positioned modelling as a central didactical tool for achieving interdisciplinarity in mathematics and science education, demonstrating how it can connect concepts across disciplines, structure teaching activities, and develop interdisciplinary competencies.

Højgaard Jensen and Jankvist (2018, *Disciplinary competence descriptions for external use*), on the other hand, addressed modelling more implicitly in relation to fostering productive communication between mathematics and other disciplines. Together, these studies underscore the dual role of modelling as both a practical strategy for teaching and a theoretical lens for developing competencies and interdisciplinary connections.

The papers in the special issue

This 2025 special issue of NOMAD comprises eight papers authored by researchers from Denmark, Norway, and Sweden. The call for papers resulted in 16 submissions, corresponding to an acceptance rate of 50 %. Although the call invited contributions from both Nordic and Baltic countries, only papers from the Nordic region were submitted.

An overview of the papers in the special issue

This special issue explores mathematical modelling in diverse educational contexts. We now briefly present the papers in four thematic pairs: *Modelling in university-level Biology*, *Teacher preparation for modelling*, *Vocational and socio-ecological contexts*, and *Digital tools and data-driven modelling*. Each section synthesizes the aims and findings of two related studies, highlighting shared themes, contrasts, and implications, as well as making connections to prior research on modelling published in NOMAD (when adequate).

Modelling in university-level Biology

Two of the papers (Tetaj and Rogovchenko & Rogovchenko) address biology at the university level and share a common concern about how students navigate the intersection of biological and mathematical discourses when engaging in modelling tasks. Tetaj focuses on a lecture's teaching goals in an interdisciplinary graduate course on fisheries stock assessment, identifying aims such as familiarizing students with fisheries discourse, fostering belonging across disciplinary communities, and supporting engagement with technical language and tools. These goals underpin a pedagogy that emphasizes authentic tasks and practical utility, helping students transition between discourses and prepare for professional practice. Like in the study by Treffert-Thomas et al. (2017), insights are also given about university lecturers' views on the teaching of mathematical modelling.

Complementing Tetaj's study, Rogovchenko and Rogovchenko examine how semantic differences between biology and mathematics influence undergraduates' reasoning during modelling activities. Their findings reveal that students often interpret key terms, such as population density and carrying capacity, through a biological lens, which can overshadow mathematical reasoning and hinder mathematisation, a topic also discussed in Blomhøj (1993). Together, the two studies of Tetaj and Rogovchenko and Rogovchenko highlight a dual challenge, namely that while interdisciplinary modelling offers rich opportunities for integration, it also exposes conceptual and linguistic tensions that require deliberate pedagogical strategies. Both papers call for careful task design and explicit attention to terminology to bridge gaps and support meaningful engagement with modelling, which reinforces the main argument by Jankvist et al. (2013) and Højgaard Jensen and Jankvist (2018).

Teacher preparation for modelling

Two of the studies (Helder Naylor & Jakobsen and Kanwal & Berget) address challenges to the preparation of teachers of mathematics (cf. Niss, 1994) and the question of how educators conceptualize and implement modelling in school mathematics. Helder Naylor and Jakobsen demonstrate that targeted professional development can significantly enhance teachers' modelling-specific pedagogical content knowledge (MsPCK), improving their understanding of modelling cycles, task characteristics, and instructional strategies. Kanwal and Berget, however, reveal persistent gaps in teachers' conceptions and practices, particularly at the primary level, where modelling is often narrowly understood and implemented through textbook tasks. This reliance on textbooks aligns with Grave and Pepin's (2015) finding that mathematics textbooks are the most frequently used and influential resource for Norwegian primary school teachers. While lower secondary teachers in Kanwal and Berget show stronger alignment with curriculum aims, both groups report challenges in task selection, guidance, and assessment. Teachers' concerns about task selection appear consistent with Berget's (2022) analysis of Norwegian mathematics textbooks and exam tasks and Frejd's (2013) analysis of Swedish mathematics textbooks. Both pinpointed a lack of holistic modelling tasks, which limits the availability of tasks that support the development of modelling competencies.

Taken together, these findings underscore the importance of sustained and differentiated professional development. Short courses can build foundational knowledge, but systemic support and resources are needed to translate this knowledge into classroom practice. Both studies point to the need for coherence across school levels and for teacher education programs to address cognitive aspects of modelling alongside practical implementation, hence providing at least a partial answer to Kadijevich's (1999) concerns how to avoid risks and limitations of adopting an overly narrow perspective on modelling.

Vocational and socio-ecological contexts

Both the studies of Frejd and Steffensen extend the discussion of modelling beyond traditional mathematics classrooms, illustrating its potential to connect mathematics with real-world concerns. Frejd emphasizes vocational relevance, showing how authentic tasks (such as hair colouring and sawing patterns) integrate mathematics with professional practices, fostering collaboration, accountability, and practical application. Steffensen, in contrast, positions modelling as a tool for critical engagement akin to Kacerja et al. (2017), but for socio-ecological issues, using contexts like artificial turf and wind farms to stimulate reflective dialogue about environmental justice and sustainability. This is also in line with Skovsmose and Säljö (2008), who pinpointed the need to include a critical conception of mathematics in more inquiry-based mathematics teaching, thus in modelling also, and the imperative of "facilitating critical reflections as part of the processes of learning mathematics" (p. 46).

Despite their different settings, both studies advocate for modelling that transcends technical problem-solving such as discussed by for example Nortvedt (2010) and Riesbeck (2006). Frejd highlights its role in career readiness and authentic learning, while Steffensen underscores its capacity to empower students as critical citizens. Together, they demonstrate how modelling can serve as a bridge between mathematics and broader societal or vocational realities, provided that tasks are designed to promote authenticity, complexity, and meaningful reflection; the latter resonating with the emphasis found in Stillman's (1998).

Digital tools and data-driven modelling

The last pair of papers (Afram & Hadjerrouit and Hellsten Østergaard & Jessen) examines the interplay between technology and modelling processes, an aspect that has not explicitly been discussed in previous NOMAD papers on modelling but touched upon by Hähkiöniemi et al. (2013). Afram and Hadjerrouit focus on digital tools as mediators of group interaction, identifying social affordances, such as common focus and authority of the tool, that shape collaboration across modelling phases. Hellsten Østergaard and Jessen, meanwhile, explore how data drives inquiry in mathematical and statistical modelling, enabling autonomy and innovation while supporting praxeological development through actions like filtering and visualizing.

The two studies highlight technology's dual role as both an enabler and a challenge, which is also the case with digital technologies in mathematics education in general, and for supporting students' Allgemeinbildung as the review by Gerster Johansen (2023) reveals. While digital tools and data can foster collaboration and investigative thinking, they also introduce complexities that require teacher orchestration and conceptual scaffolding. These findings call for task designs that leverage technological affordances without compromising depth of understanding, and for professional development that equips teachers to manage these dynamics effectively.

Summary

In contrast to the foci of previous papers in NOMAD on modelling, the eight papers in this special issue manifest a strong focus on the teaching of modelling and new perspectives compared to the early discussion which was more oriented towards theoretical issues and students' learning (cf. Niss (1994); Mousoulides et al. (2007); Skov Hansen et al. (1999)). Collectively, however, the contributions in this special issue demonstrate modelling's multifaceted role in education, from bridging disciplinary boundaries and enhancing teacher competence to promoting vocational relevance, socio-ecological awareness, and digital collaboration. They reveal both opportunities and challenges, emphasizing the need for continued research on pedagogical strategies, curriculum alignment, and teacher professional development to fully realize modelling's potential in diverse educational settings.

Plurality in theoretical framings and perspectives used

According to Niss (2007), one hallmark of a high-quality scientific paper is the explicit use of a theoretical framework. In the research literature on mathematical modelling in mathematics education, a wide range of theoretical approaches has been applied for different purposes (Geiger & Frejd, 2015). These approaches span from local modelling theories (Kaiser & Sriraman, 2006), which are specific to modelling education, to more general theories drawn from mathematics education as a whole (Sriraman & English, 2010), and in some cases, no theoretical framework at all (Geiger & Frejd, 2015).

To capture the diversity and richness of theoretical approaches represented in this special issue, we analysed which local and general theories have been employed, how they have been combined, and, where possible, the rationale behind their selection for particular research purposes. The result of our analysis is presented in table 1 below.

Table 1. *Summary of the analysis of local and global theoretical frameworks.*

Author	Local modelling theories	General theories
Afram and Hadjerrouit	Modelling cycle (Blum & Leiß, 2007)	Affordance Theory (Gibson, 1977)
Frejd	SoMM (Frejd & Vos, 2024)	
Helder Naylor and Jakobsen	MsPCK (Borromeo Ferri, 2018)	PCK (Shulman, 1987)
Hellsten Østergaard and Jessen		ATD (Chevallard, 2019), SRP (García et al., 2006)
Steffensen		Critical mathematics education (Skovsmose, 2023)
Tetaj		Commognition (Sfard, 2008)
Rogovchenko and Rogovchenko	Modelling competency (Niss & Blum, 2020)	Social culture (Vygotsky, 1986)

All papers in this special issue use one or more theoretical frameworks, which is considered an indicator of scientific quality (cf. Niss, 2007). From Table 1, we observe considerable diversity in the use of these frameworks. All papers, except one (Frejd), apply general theoretical frameworks, and three of these six also combine them with a local framework.

Three contributions integrate both local modelling theories and broader theoretical perspectives. Afram and Hadjerrouit combine Gibson's Affordance Theory, extended through Cultural-Historical Activity Theory, with the Modelling Cycle. This dual approach frames how digital tools mediate collaborative modelling and structures the phases of students' modelling activities. Similarly, Helder Naylor and Jakobsen merge Pedagogical Content Knowledge (PCK) with modelling-specific PCK (MsPCK), complemented by Borromeo Ferri's construct of modelling-specific teaching competencies, emphasizing teacher knowledge as central for effective modelling in primary classrooms. Rogovchenko and Rogovchenko draw on Vygotskian perspectives and interdisciplinary mathematics education while applying modelling competencies (Niss & Blum, 2020), focusing on semantic and linguistic challenges in interdisciplinary modelling.

Three other papers rely exclusively on general theories from mathematics education or related fields. Hellsten Østergaard and Jessen employ the Anthropological Theory of the Didactic (ATD) and Study and Research Paths (SRP) to conceptualize modelling as inquiry-based learning. Steffensen adopts a critical mathematics education perspective, framing modelling as a tool for democratic dialogue and engagement with socio-political issues such as sustainability. Tetaj applies Sfard's commognitive framework to analyse interdisciplinary discourse, focusing on how mathematical and biological narratives merge in modelling contexts.

Finally, one paper uses only a local framework. Frejd employs the Spirit of Mathematical Modelling (SoMM), a theory developed specifically for modelling education. SoMM in Frejd's paper provides analytical principles, guiding the evaluation of modelling-rich vocational tasks without combining any general theory.

Compared to the findings of Geiger and Frejd (2015), the current analysis reveals a notable shift in the theoretical landscape of research on mathematical modelling in mathematics education. Geiger and Frejd reported that local theories were dominant and strongly focused around only two approaches, the modelling cycle and modelling competencies, which were used more frequently than all general theoretical approaches combined. They argued that while this concentration might indicate coherence within the research field, it also risked creating an overdependence on a narrow set of frameworks, potentially constraining the richness and diversity of theoretical perspectives.

In contrast, the present special issue demonstrates greater theoretical variety. Although the modelling cycle and modelling competencies still appear, they are no longer the sole local frameworks in use. The inclusion of SoMM (Spirit of Mathematical Modelling) and modelling-specific MsPCK suggests an expansion of locally grounded theories. Furthermore, the integration of general frameworks such as Affordance Theory, Cultural-Historical Activity Theory, ATD, Commognition, and Critical mathematics education indicates a broader engagement with theoretical perspectives beyond modelling-specific constructs. This diversification reflects a trend toward combining local and general theories to address complex research questions, as seen in three contributions that explicitly merge these approaches.

Despite this progress, some concerns raised by Geiger and Frejd (2015) remain relevant. White spots persist where theoretical approaches have yet to be applied to modelling research. Sociological theories, feminist perspectives, ethnomathematics, and neuroscience remain largely unexplored in this context. Following Sriraman and English's (2010) view that advancement in mathematics education often occurs through adapting theories from within and outside the field, these gaps represent opportunities for further theoretical enrichment. Expanding into these areas could foster greater diversity and innovation, reduce the risk of theoretical stagnation and enable new insights into modelling practices.

Taken together, the comparison suggests that while the field has moved toward greater theoretical diversity since Geiger and Frejd's (2015) study, continued efforts are needed to explore underutilized frameworks and maintain a balance between coherence and openness to new perspectives.

Diversity in implemented methods and analysis

Another key quality criterion in educational research, linked to theoretical framing, is the choice of methodological approaches (Schoenfeld, 2010). Research design and corresponding analytical methods are crucial for producing justifiable and generalisable answers to research questions (Niss, 2010). To provide an overview of the designs and methods used in the papers included in this special issue, we examine whether the research design is qualitative or quantitative, the data collection methods, participants' characteristics, and approaches to data analysis.

Research Design

Among the eight papers included in this special issue, only one employs a quantitative research methodology. The study by Helder Naylor and Jakobsen, focusing on modelling specific PCK of mathematics teachers, uses a quantitative pre- and post-test design involving 15 Norwegian teachers following a part of a PD course.

The research design dominating the qualitative papers is the case study (four of them explicitly identify this). The purpose of case studies is for the researcher to "elucidate the unique features of the case" (Bryman, 2012, p. 69), which appears to characterize most of the papers in this special issue. These studies prioritize the exploration of processes and contexts rather than outcomes, reflecting the interpretive orientation that underpins research on mathematical modelling. The cases study different processes: Afram and Hadjerrouit focus on exploring how digital tools mediate students' group interactions during mathematical modelling, while situated in authentic classroom settings with students sharing a single computer per group; Tetaj investigates the teaching goals for mathematical modelling in the interdisciplinary context of one course on mathematical models in fisheries stock assessment; Kanwal and Berget, explore mathematics teachers' conceptions and practices regarding mathematical modelling; and Hellsten Østergaard and Jessen focus on the role of data in modelling processes by revisiting two previously implemented classroom cases. Rogovchenko and Rogovchenko apply an extracurricular teaching experiment with biology students taking a mathematical modelling course at a Norwegian university.

The two remaining studies employing qualitative methodologies, by Frejd and Steffensen, adopt different research designs. Both focus on analysing the potentials of tasks and activities in mathematical modelling: Frejd analyses how two activities in Swedish vocational education embody mathematical modelling aspects to emphasize their potentialities in fostering the Spirit of mathematical modelling (SoMM); Steffensen on the other hand, bases her study on the analysis of two mathematical modelling tasks, previously designed by her, to discuss their potential to being used for reflective discussions contributing on students' awareness of socio-ecological issues in the mathematics classroom.

Data collection methods

Data collection methods vary across studies. Video recordings and screen capture feature prominently in Afram and Hadjerrouit's classroom-based case study, while Hellsten Østergaard and Jessen rely on audio-recorded observations. Rogovchenko and Rogovchenko use audio recordings of small-group discussions during extracurricular modelling sessions. Interviews are common: Tetaj conducts a semi-structured narrative interview with a biology professor, supplemented by observations and lecture notes; Kanwal and Berget interview ten Norwegian teachers about their conceptions and practices. Frejd draws on narrative accounts from classroom observations, whereas Steffensen and Hellsten Østergaard and Jessen analyse tasks and classroom interactions using theory-driven frameworks. The quantitative study by Helder Naylor and Jakobsen employs a standardized instrument adapted for primary teachers.

Participant characteristics

Participants span diverse educational contexts. Three of the papers focus on pre-university students: Aframi and Hadjerrouit analyse data from 13 Norwegian students in grades 9-12; Hellsten Østergaard and Jessen focus on two groups of Danish students, respectively in grade 5 and upper secondary school; Frejd focuses on narrative accounts of Swedish vocational education students. Two papers target teachers: Kanwal and Berget interviewed 10 Norwegian teachers in grades 5-10, while the quantitative study by Helder Naylor and Jakobsen focuses on 15 Norwegian primary school teachers. Two other studies in the field of biology are focused on a university level, with Tetaj following a biology professor, and Rogovchencko and Rogovchenko focusing on undergraduate biology students. The study by Steffensen does not focus on specific participants, as it focuses on task analysis.

Approaches to Data Analysis

Analytical strategies reflect the diversity of research aims. Two of the papers used thematic analysis (Braun & Clarke, 2006): Tetaj used an inductive approach, with initial codes focusing on teaching aims, student challenges and instructional strategies and where the commognitive perspective by Sfard guided the interpretative process; Afram and Hadjerrouit, implemented an inductive and deductive approach to the group work data to identify patterns in student dialogue and tool use, guided by three predefined categories from Affordance Theory and adding a new category. Grounded theory was used by Kanwal and Berget to analyse teacher interviews, starting from open coding, followed by categories emerging from similar codes.

Two studies used a theory-driven analysis and frameworks. The two cases in the Hellsten Østergaard and Jessen paper were analysed using the Anthropological Theory of the Didactic (ATD) through question–answer dialectics and media–milieu dynamics. Steffensen uses theoretical constructs from Critical Mathematics Education to reflect upon the potential that the two analysed MM tasks have for facilitating reflective discussions of socio-ecological issues. Frejd, who bases his analysis on the Spirit of mathematical modelling, used a template approach for the analysis of the data from the narrative accounts.

Rogovchenko and Rogovchenko used an interpretative framework centred on semantic aspects of terminology in interdisciplinary modelling and drawing on theories such as the Vygotskian socio-cultural theory and the modelling cycle. The quantitative study by Helder Naylor and Jakobsen analysed test data using non-parametric methods (Mann–Whitney and Fisher's tests).

Summary

Based on the research designs and methods discussed in this section, the papers in this special issue appear to mirror international trends in mathematical modelling research, with a strong dominance of qualitative approaches. Specifically, 87% of the papers employ qualitative designs, primarily case studies. This prevalence aligns with findings from previous reviews (Cevikbas et al., 2023; Krawitz et al., 2025; Schukajlow et al., 2018), where the proportion of quantitative studies was comparatively low - 11%, 25% and 7% respectively. The reviews report that qualitative methodologies dominate modelling research due to their suitability for exploring processes, contexts, and participant perspectives. Case studies, in particular, remain the preferred design for capturing the complexity of classroom practices and teachers' challenges and ideas of teaching mathematical modelling, with a prevalence of 55% of the papers in the Krawitz et al. (2025) review. Furthermore, the quantitative study by Helder Naylor and Jakobsen, which measures in-service teachers' modelling specific PCK, aligns with the findings of Krawitz et al. (2025), where most quantitative studies concentrate on fostering competencies.

Data analysis methods also show considerable variation, reflecting the diversity of research aims and theoretical framings. This methodological diversity illustrates the field's reliance on interpretative approaches but also highlights the need for more systematic and comparable analytical strategies to strengthen cumulative knowledge. Despite the richness of qualitative insights, the limited presence of quantitative and mixed-methods studies raises concerns about generalisability and theory building. Expanding such approaches would enable researchers to evaluate the effectiveness of interventions, develop robust measurement tools, and complement qualitative findings (Cevikbas et al., 2023; Schukajlow et al., 2018).

Regarding study participants, this special issue includes no research focusing on pre-service teachers, and only one study drawing on primary school data. Yet, Mousoulides, Sriraman and Christou (2007) urged the mathematics education community to continually think, and research, about mathematical modelling for younger students. The remaining studies in this special issue are situated at the secondary level, while the in-service teacher studies address both primary and secondary education. This imbalance suggests a need for research targeting early educational stages and teacher preparation programs, particularly given evidence that modelling remains underdeveloped in school practice and teachers at both lower and upper secondary levels in the Nordic context are generally not familiar with mathematical modelling (Berget, 2023; Burner et al., 2022).

In summary, while the contributions in this issue provide valuable insights into modelling practices, pedagogical challenges and analytical approaches, future research could benefit from a broader range of methodological and analytical strategies. Incorporating more quantitative and mixed-methods designs, alongside systematic frameworks for data analysis, could enhance generalisability, support theory development and, in the long term, advance the integration of mathematical modelling in education.

Final remarks and looking ahead

This special issue highlights the growing diversity and maturity of Nordic research on mathematical modelling in education. The contributions span multiple educational levels, from primary classrooms (Helder

Naylor & Jakobsen), secondary (Afram & Hadjerrouit; Hellsten Østergaard & Jessen; Kanwal & Berget) to vocational (Frejd) and higher education contexts (Tetaj; Rogovchenko & Rogovchenko) and employ a wide range of theoretical frameworks (cf. Geiger & Frejd, 2015; Kaiser & Sriraman, 2006) and methodological approaches. Collectively, they underscore modelling's potential to connect mathematics with real-world problems, foster interdisciplinary thinking (cf. Jankvist et al., 2013; Højgaard Jensen & Jankvist, 2018), and support critical engagement with societal issues (cf. Kacerja et al., 2017; Skovsmose 1992, 1994). Despite these advances, several gaps remain of the one discussed by Niss (1994). Qualitative case studies dominate the field, offering rich insights into processes and contexts, but limiting generalizability. Quantitative and mixed-methods research is needed to complement these findings, evaluate the effectiveness of interventions, and strengthen theory building. Similarly, participant profiles reveal underexplored areas such as primary education and pre-service teacher preparation. Theoretical diversity has increased, yet perspectives such as those from sociology and ethnomathematics remain largely absent, representing opportunities for future work.

Looking ahead, research could productively continue the work within biology, including sustainability, social sciences, and vocational education, but also expand into interdisciplinary domains beyond these (cf. Højgaard Jensen & Jankvist, 2018). Digital technologies and data-driven modelling offer promising avenues for authentic classroom integration, while robust instruments for assessing modelling competencies (cf. Skov Hansen et al., 1999) and pedagogical content knowledge are essential for advancing both research and practice (cf. Niss, 1994; 2007). Continued efforts to combine local modelling theories with broader educational frameworks, and to adapt theories from outside mathematics education, will enrich the field and address complex educational challenges. Finally, based on the work presented in this special issue, we argue that Nordic researchers are well positioned to advance global conversations on modelling through sustained collaboration within ICTMA, CERME, and NOMAD. By promoting theoretical innovation, methodological diversity, and practical relevance, future research can strengthen modelling's role as a cornerstone of mathematics education, empowering students as critical citizens capable of addressing real-world and socio-ecological challenges.

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Notes

1 International Congress on Mathematical Education

2 Conference of the European Society for Research in Mathematics Education

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