Advancing Mathematical Modelling Instruction: A Systematic Review of Evidence-Based Practices

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Abstract:

This study examines recent literature on the key dimensions and frameworks underlying mathematical modelling instruction. A systematic literature review (SLR) was conducted following the PRISMA protocol, involving the stages of identification, screening, eligibility, inclusion, and synthesis. Data were gathered from three major databases: ERIC, ScienceDirect, and Scopus. From an initial pool of 436 studies, 18 articles met the inclusion criteria and were analyzed in depth. The findings reveal that effective mathematical modelling instruction is built upon a balanced integration of three core dimensions: activity design, pedagogy, and assessment systems. Among these, activity design emerged as the most emphasized, particularly highlighting the importance of authentic, relevant, and open-ended tasks that promote learner engagement and critical thinking. Pedagogical practices focused on teacher facilitation and student-centered learning, while assessment systems addressed the evaluation of both cognitive and process-oriented competencies. The review also indicates that research in this field is predominantly contributed by scholars from Germany, the United States, Turkey, Australia, and Singapore, with a strong focus on secondary education contexts. These results underscore the need for more balanced development across all dimensions and expanded research in diverse educational settings.

Keywords: mathematical modelling, systematic literature review, instructional design

Introduction:

Mathematical modelling is increasingly recognized as a cornerstone of modern mathematics education, playing a critical role in enhancing learners' mathematical proficiency while cultivating informed and responsible citizenship. By engaging students in real-world problem-solving, modelling enables them to connect abstract mathematical concepts with authentic societal issues. Unlike traditional problem-solving approaches that often rely on simplified or idealized conditions, mathematical modelling begins with complex, "unedited" real-world situations and requires learners to interpret, represent, and validate results within their original context.

Recent developments in mathematics education emphasize the importance of evidence-based instructional practices to improve learning outcomes across diverse student populations. A growing body of literature highlights that effective mathematics teaching must be grounded in research-informed strategies that integrate conceptual understanding, procedural fluency, and application skills (Knogler, M. et al., 2022; Doabler, C. T. et al., 2021). These studies underscore the necessity of aligning classroom practices with empirically validated approaches, particularly in areas such as modelling, where instructional complexity is high.

In addition, inclusive and differentiated mathematics instruction has become a priority in contemporary educational systems. Research indicates that learners with diverse needs—including those with developmental disabilities and autism spectrum disorder—benefit significantly from structured, explicit, and evidence-based mathematical interventions (Spooner, F. et al., 2019; King, S. A. et al., 2016). These findings reinforce the importance of designing modelling instruction that is not only cognitively demanding but also accessible and adaptable to varied learner profiles. Similarly, inclusive pedagogical frameworks advocate for equitable participation and meaningful engagement in mathematical tasks across all levels of ability (Radzi, N. M. & Mahmud, M. S., 2025).

Despite its recognized value, the integration of mathematical modelling into classroom practice remains inconsistent. Many educators experience challenges due to limited access to structured resources, insufficient professional preparation, and a lack of confidence in facilitating open-ended, student-centered tasks. Earlier work on reforming mathematics pedagogy emphasizes that shifts toward inquiry-based and application-driven instruction require sustained support, targeted training, and systemic alignment (Hodara, M., 2011). These barriers are particularly evident among pre-service teachers, whose limited exposure to modelling frameworks often results in fragmented or superficial implementation.

Furthermore, recent scholarship has expanded the discussion of modelling beyond mathematics to include interdisciplinary and model-based teaching approaches. For instance, syntheses of modelling pedagogies in science education highlight the value of expansive, integrative frameworks that promote critical thinking and knowledge transfer across domains (Carroll, G. & Park, S., 2026). Similarly, emerging research demonstrates the application of mathematical thinking in fields such as medicine, reinforcing the relevance of modelling in addressing complex, real-world challenges (Taja-on, E. P. et al., 2024).

Given these developments, there is a growing need to synthesize existing research on the dimensions and frameworks that guide mathematical modelling instruction. While numerous studies propose different approaches, there remains a lack of coherence in how these frameworks are structured, implemented, and evaluated across educational contexts. A systematic examination of these elements is essential to identify patterns, gaps, and best practices that can inform both research and classroom application.

This study addresses this need by synthesizing current literature on mathematical modelling instruction, with a particular focus on identifying its core dimensions and sub-dimensions, as well as the frameworks used in school-based contexts. By providing a comprehensive overview of existing evidence, this research aims to support educators, curriculum developers, and policymakers in designing more effective, inclusive, and evidence-based modelling instruction for learners across educational levels.

Literature Review:

Mathematics education has increasingly shifted toward evidence-based and learner-centered approaches, emphasizing conceptual understanding, problem-solving, and real-world application. Recent meta-analyses highlight the growing influence of digital technologies in enhancing conceptual understanding in higher education mathematics, particularly through interactive tools, simulations, and adaptive learning environments (Sofroniou, 2025). These developments align with broader educational reforms that advocate for integrating technology not merely as a supplement but as a transformative component of instruction.

The integration of artificial intelligence (AI) in mathematics education further strengthens this transformation. Studies demonstrate that AI-driven tools and predictive models can support personalized learning pathways, optimize instructional decisions, and enhance student engagement (He et al., 2025). Similarly, AI-supported modelling environments have been shown to improve students' ability to explore scientific and mathematical models, particularly at the secondary level (Vorsah & Tamakloe, 2025). These findings suggest that technology-enhanced modelling instruction has the potential to bridge the gap between theoretical knowledge and real-world application.

Alongside technological advancements, the importance of evidence-based instructional practices remains central. Foundational research on teaching students with severe developmental disabilities emphasizes structured, explicit instruction and systematic interventions as key to improving mathematical outcomes (Spooner et al., 2012). Parallel studies focusing on learners with autism spectrum disorder also highlight the effectiveness of targeted, research-based interventions in promoting mathematical understanding (Barnett & Cleary, 2015). These perspectives reinforce the need for modelling instruction that is both rigorous and inclusive.

The design of mathematical modelling tasks has been extensively explored in recent literature. Frameworks developed for fostering modelling competencies emphasize the importance of authenticity, openness, and contextual relevance in task design (Geiger et al., 2022). These characteristics enable students to engage deeply with problems, make assumptions, and iteratively refine their models. Such frameworks provide a structured approach to designing modelling activities that move beyond routine exercises toward meaningful problem-solving experiences.

Pedagogical practices in mathematics education have also evolved significantly over the past decades. A comprehensive review of teaching practices highlights the shift toward practice-based pedagogies that prioritize student thinking, discourse, and active engagement (Charalambous & Delaney, 2020). These approaches align with modelling instruction, where teachers act as facilitators guiding students through complex problem-solving processes rather than simply delivering content.

Analytical thinking has emerged as a critical component of mathematical competence, particularly in modelling contexts. A systematic review by Wang et al. (2025) indicates that developing students' analytical skills requires exposure to diverse problem types, opportunities for reasoning, and structured reflection. This aligns with modelling activities, which inherently demand higher-order thinking skills, including analysis, evaluation, and synthesis.

Broader trends in mathematics education research reveal a growing emphasis on systematic reviews and meta-analyses to inform practice. A meta-review by Cevikbas et al. (2024) identifies increasing interest in modelling, technology integration, and competency-based education. These trends indicate a shift toward more holistic and interdisciplinary approaches to mathematics teaching and learning.

Teacher preparation plays a crucial role in the successful implementation of modelling instruction. Research on pre-service mathematics teachers highlights the need for targeted training to enhance mathematical thinking, pedagogical knowledge, and confidence in facilitating complex tasks (Mafarja et al., 2026). Without adequate preparation, teachers may struggle to implement modelling effectively, leading to inconsistent learning experiences.

Technology's role in supporting sustainable and equitable education has also been widely discussed. Systematic reviews emphasize that digital tools can promote access, engagement, and innovation in mathematics education, contributing to global goals such as quality education (Meylani, 2025). However, the effectiveness of these tools depends on their alignment with pedagogical objectives and instructional design.

Theoretical and philosophical perspectives further deepen the understanding of mathematical modelling. Scholars argue that modelling is not merely a pedagogical strategy but a way of thinking that connects mathematics to human experience and societal challenges (Frejd & Vos, 2024). Similarly, modelling in STEM education is viewed as essential for fostering authenticity and interdisciplinary learning (Hallström & Schönborn, 2019).

Instructional approaches such as problem-based learning (PBL), project-based learning (PjBL), and case-based learning (CBL) have also been identified as effective strategies for promoting active and evidence-based learning in mathematics and related fields (Sukackė et al., 2022; Ayari et al., 2025). These approaches share common principles with modelling instruction, including student-centered learning, real-world relevance, and collaborative problem-solving.

Hence, the growing emphasis on evidence-based teaching practices across disciplines underscores the importance of systematic observation and evaluation. Tools such as classroom observation protocols and evidence-based design frameworks provide valuable insights into effective teaching practices (Eddy et al., 2015; Halawa et al., 2020). In the context of mathematical modelling, such tools can support the development and assessment of instructional practices, ensuring alignment with research-based standards and continuous improvement in teaching and learning.

Methodology:

This study employed a Systematic Literature Review (SLR) guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol to ensure a rigorous and transparent research process. The review began with the identification phase, where comprehensive searches were conducted across three major academic databases: ERIC, ScienceDirect, and Scopus. Boolean search strings such as (“framework” OR “model”) AND (“modelling”) AND (“mathematics education”) were utilized to capture relevant studies. This initial search yielded a total of 436 articles.

During the screening phase, duplicate records were removed, reducing the dataset by 64 entries. The remaining articles were then filtered based on predefined criteria, including publication year (2018–2024) to ensure contemporary relevance and inclusion of peer-reviewed journal articles written in English. This process helped refine the dataset to studies most aligned with current developments in mathematical modelling instruction.

In the eligibility phase, 41 articles were subjected to a detailed manual review. Each study was assessed against specific inclusion criteria, particularly its focus on mathematical modelling within an educational context and the presence of an explicit instructional framework. Articles that did not meet these criteria were excluded to maintain the quality and relevance of the review.

In the inclusion phase, backward and forward citation tracking (snowballing) was conducted to identify additional relevant studies that may not have appeared in the initial database search. This process resulted in the inclusion of five additional articles, bringing the final sample to 18 studies. These selected articles formed the basis for qualitative synthesis and analysis, enabling the researchers to identify key dimensions, patterns, and trends in mathematical modelling instruction.

Findings and Discussion:

Instructional Dimensions
The analysis of the selected studies revealed that mathematical modelling instruction is structured around three primary and interrelated dimensions: the design of activities or tasks (48%), pedagogy (38%), and assessment systems (14%). These dimensions collectively shape how modelling is conceptualized, implemented, and evaluated in educational contexts, reflecting a balanced yet uneven emphasis across instructional components.

The design of activity or task emerged as the most dominant dimension, underscoring the centrality of well-constructed problems in modelling instruction. This dimension focuses on the development of tasks that are authentic, open-ended, and grounded in real-world contexts. Such tasks require students to engage in interpretation, assumption-making, and iterative problem-solving, aligning with broader instructional design principles that integrate learning theories with practice (Abuhassna et al., 2024). The prominence of this dimension suggests that the quality of tasks largely determines the depth of students' modelling experiences.

Moreover, task design in modelling is closely associated with fostering creativity and higher-order thinking skills. Research indicates that instructional practices emphasizing open and complex problems can significantly enhance students' mathematical creativity and problem-solving abilities (Bicer, 2021).

Similarly, problem-based learning approaches reinforce the importance of designing tasks that challenge students to apply knowledge in meaningful ways, moving from procedural understanding to performance-based outcomes (Ayari et al., 2025). The emphasis on task design also reflects the interdisciplinary and authentic nature of modelling. Studies in STEM education highlight that meaningful integration of mathematics and science relies heavily on tasks that simulate real-world phenomena and encourage cross-disciplinary thinking (Ahr et al., 2026; Hallström & Schönborn, 2019). From a philosophical perspective, modelling tasks serve as a bridge between mathematics and human experience, reinforcing the idea that mathematics is not merely abstract but deeply connected to societal contexts (Frejd & Vos, 2024).

The second dimension, pedagogy, highlights the critical role of teachers in facilitating modelling instruction. This dimension encompasses teaching strategies, classroom interactions, and the overall learning environment. Effective pedagogical approaches emphasize active learning, student engagement, and guided inquiry, where teachers act as facilitators rather than knowledge transmitters. Evidence-based practices such as peer instruction and collaborative learning have been shown to significantly improve conceptual understanding and student participation (Vickrey et al., 2015).

In the context of mathematical modelling, pedagogy also involves equipping teachers with the necessary competencies to guide students through complex and often ambiguous problem-solving processes. Teacher education research stresses the importance of preparing educators to handle the dynamic nature of modelling tasks, including managing multiple solution pathways and supporting student reasoning (Ferri, 2018). This is particularly important in addressing diverse learner needs, including emergent multilingual students who require adaptive and inclusive instructional strategies (Ganesan, 2025).

Technological advancements further influence pedagogical practices in modelling instruction. AI-driven educational tools and data-driven decision-making systems enable teachers to personalize instruction, monitor student progress, and provide targeted interventions (He et al., 2025). Additionally, modelling education in disruptive contexts—such as during global crises—has highlighted the need for flexible and innovative pedagogies that can adapt to changing learning environments (Siller et al., 2024).

The third dimension, assessment systems, although the least represented, plays a crucial role in evaluating students' modelling competencies. Assessment in modelling extends beyond traditional testing to include the evaluation of processes such as reasoning, collaboration, and the ability to justify solutions. This aligns with evidence-based approaches that advocate for continuous and formative assessment practices in STEM education (Eddy et al., 2015). Furthermore, assessment systems in modelling must account for the complexity and variability of student responses. Unlike conventional problems with fixed answers, modelling tasks often yield multiple valid solutions, requiring assessment frameworks that are flexible and criteria-based. Evidence from engineering and STEM education suggests that integrating performance-based and authentic assessment methods can enhance the evaluation of student learning outcomes (Sukackė et al., 2022).

The distribution of these dimensions indicates a strong emphasis on task design and pedagogy, with comparatively less focus on assessment systems. This imbalance suggests a potential gap in the literature, where the development of robust and comprehensive assessment frameworks for modelling remains underexplored. Addressing this gap is essential for ensuring that all dimensions of modelling instruction are aligned and effectively support student learning.

Sub-Dimensions

A deeper analysis of the instructional dimensions reveals a set of sub-dimensions that further specify how mathematical modelling instruction is designed, implemented, and assessed. These sub-dimensions provide a more granular understanding of the competencies and practices required for effective modelling, particularly across pedagogy, task design, and assessment systems.

Within the pedagogical dimension, theoretical knowledge emerges as a foundational sub-component. Teachers are expected to possess a strong understanding of mathematical concepts, modelling cycles, and learning theories to effectively guide students through complex problem-solving processes. Research on mathematics pedagogy emphasizes that instruction grounded in evidence-based practices leads to improved student outcomes, particularly when teachers can connect theory to classroom implementation (Hodara, 2011; Charalambous & Delaney, 2020).
Another critical pedagogical sub-dimension is task-related competency, which refers to the teacher's ability to interpret, adapt, and facilitate modelling tasks. This competency is essential in helping students navigate open-ended problems and construct meaningful mathematical representations. Studies indicate that teachers who are skilled in managing modelling tasks can better support students' analytical thinking and problem-solving abilities (Wang et al., 2025; Mafarja et al., 2026).

Diagnostic competency also plays a significant role in pedagogy, particularly in identifying students' misconceptions and learning difficulties during the modelling process. Effective teachers continuously assess student understanding and adjust instruction accordingly. Evidence-based research highlights the value of formative assessment and observation in capturing "practice-based evidence" of learning, enabling more responsive and targeted teaching (Doabler et al., 2021).

Closely related to diagnostic skills is the knowledge of instructional interventions, which involves selecting and implementing strategies to address diverse learner needs. Inclusive mathematics education research underscores the importance of differentiated instruction and tailored interventions, especially for students with developmental disabilities or autism spectrum disorder (Spooner et al., 2012; Barnett & Cleary, 2015; Radzi & Mahmud, 2025). These sub-dimensions ensure that modelling instruction remains equitable and accessible.

In terms of task design sub-dimensions, the concept of reality is central to mathematical modelling. Tasks must be grounded in authentic, real-world contexts that reflect the complexity and ambiguity of real-life situations. This aligns with modelling frameworks that emphasize the importance of connecting mathematics to lived experiences and societal issues (Geiger et al., 2022; Taja-on et al., 2024).

Another important aspect of design is relevance, which ensures that tasks are meaningful and engaging for learners. When students perceive tasks as relevant to their lives or future careers, they are more likely to invest effort and persist in problem-solving. Interdisciplinary approaches, particularly those integrating science and mathematics, further enhance the relevance of modelling activities (Carroll & Park, 2026).

The sub-dimension of openness refers to the degree to which tasks allow for multiple solution pathways and interpretations. Open tasks encourage creativity, critical thinking, and student agency, distinguishing modelling activities from routine exercises. Trends in mathematics education research highlight the growing emphasis on such open-ended approaches as essential for developing higher-order competencies (Cevikbas et al., 2024). Additionally, the use of realistic numerical values strengthens the authenticity of modelling tasks. Instead of relying on simplified or artificial data, realistic values enable students to engage in more accurate and meaningful analysis. The integration of digital technologies and AI tools further supports this aspect by providing access to real-time data and dynamic modelling environments (Sofroniou, 2025; Vorsah & Tamakloe, 2025).

For the assessment dimension, one key sub-dimension is the complexity of models, which involves evaluating the sophistication and appropriateness of students' mathematical representations. Assessment frameworks must consider not only the final solution but also the processes involved in constructing and refining models. This aligns with contemporary approaches that emphasize process-oriented evaluation in mathematics education.
Another important sub-dimension is shareability, which highlights the communicative aspect of modelling. Students are expected to present, justify, and critique models within collaborative settings. This reflects broader educational goals of developing communication and teamwork skills, which are essential in real-world problem-solving contexts and supported by active learning frameworks.

Finally, the assessment of cognitive and social competencies underscores the holistic nature of modelling instruction. Beyond mathematical accuracy, students are evaluated on their reasoning, collaboration, and ability to reflect on their solutions. Research on technology-enhanced and sustainable education further emphasizes the importance of integrating these competencies to prepare learners for complex, real-world challenges (Meylani, 2025). Collectively, these sub-dimensions highlight the multifaceted nature of mathematical modelling instruction and the need for comprehensive frameworks that address all aspects of teaching and learning.

Institutional Level and Topics

The analysis of the selected studies reveals a clear concentration of mathematical modelling research at the secondary school level, which accounts for 71% of the reviewed literature. This dominance suggests that modelling instruction is most frequently situated within middle and high school contexts, where students are perceived to possess the cognitive readiness required to engage with complex, real-world problems. The nature of modelling characterized by abstraction, interpretation, and iterative reasoning aligns strongly with the developmental stage of secondary learners, who are transitioning toward more advanced analytical thinking (Wang et al., 2025).

One key explanation for this trend lies in the alignment between modelling tasks and established evidence-based teaching practices. Research indicates that effective mathematics instruction at the secondary level often integrates conceptual understanding, problem-solving, and application, all of which are central to modelling (Knogler et al., 2022). Furthermore, secondary curricula tend to provide greater flexibility for implementing open-ended and inquiry-based approaches, making them more conducive to modelling activities. In contrast, only 10% of the studies focused exclusively on the primary education level, highlighting a significant gap in the literature. This limited representation may stem from assumptions about younger learners' readiness to engage in modelling tasks.

However, emerging research in inclusive mathematics pedagogy argues that, with appropriate scaffolding and contextualization, primary students can meaningfully participate in modelling activities (Radzi & Mahmud, 2025). This suggests that the underrepresentation of primary-level studies may reflect a research gap rather than a pedagogical limitation.

Additionally, studies on learners with diverse needs reinforce the importance of early exposure to structured and supportive mathematical instruction. Evidence-based interventions for students with developmental disabilities and autism spectrum disorder demonstrate that carefully designed instructional strategies can facilitate engagement with mathematical concepts, including those related to modelling (Spooner et al., 2012; Spooner et al., 2019; Barnett & Cleary, 2015; King et al., 2016). These findings highlight the potential for extending modelling instruction into primary and inclusive education settings.

At the tertiary or university level, only 5% of the studies were identified, indicating relatively limited research focus. This is somewhat surprising given the increasing emphasis on higher-order thinking and real-world application in higher education. One possible explanation is that modelling at this level is often embedded within specialized disciplines such as engineering, economics, or applied sciences, rather than being explicitly framed as "mathematical modelling instruction" (Hodara, 2011).

Nevertheless, recent studies suggest that digital technologies and advanced computational tools are reshaping modelling practices in higher education. For instance, the integration of simulations, dynamic software, and AI-driven platforms has been shown to enhance conceptual understanding and support complex modelling tasks among university students (Sofroniou, 2025). These developments point to the need for further research exploring modelling instruction within tertiary contexts.

The distribution of institutional focus also reflects broader pedagogical trends in mathematics education. Practice-based pedagogies, which emphasize active learning and student engagement, are more commonly implemented in secondary settings where curriculum structures allow for flexibility (Charalambous & Delaney, 2020). Similarly, the use of technology-enhanced modelling tools has been particularly prominent in high school environments, where digital literacy is increasingly integrated into instruction (Vorsah & Tamakloe, 2025).

In terms of content focus, the findings indicate that a substantial majority (87%) of the frameworks are general in nature, addressing mathematical modelling as a holistic process rather than focusing on specific mathematical topics. This suggests that researchers and educators prioritize transferable modelling competencies such as problem formulation, representation, and validation over discipline-specific content. Such an approach aligns with frameworks that emphasize modelling as a cross-cutting skill applicable across various domains (Geiger et al., 2022). Only a small proportion of studies addressed specific mathematical topics such as probability, differentiation, or logarithmic functions. This limited focus on content-specific modelling may reflect the complexity of designing tasks that integrate both conceptual depth and real-world applicability. However, interdisciplinary research demonstrates that modelling can be effectively applied to specialized fields, including science and medicine, thereby expanding its relevance beyond general mathematics education (Carroll & Park, 2026; Taja-on et al., 2024).

The emphasis on general modelling frameworks, combined with the concentration at the secondary level, highlights both strengths and gaps in the current body of research. While the focus on broad competencies supports flexibility and transferability, the lack of attention to specific educational levels and mathematical topics suggests opportunities for future research. Expanding modelling studies into primary and tertiary contexts, as well as across diverse mathematical domains, will be essential for developing a more comprehensive and inclusive understanding of mathematical modelling instruction.

Modelling is Predominantly Situated in Secondary Education

The predominance of mathematical modelling instruction at the secondary education level is largely attributed to the inherent complexity of the modelling cycle. Modelling requires students to engage in multiple stages, including problem identification, simplification, mathematization, analysis, and interpretation. These processes demand a level of cognitive maturity that is typically more developed among secondary learners, particularly in terms of abstract reasoning and the ability to manage ambiguity in problem-solving contexts.

Secondary students are generally better equipped to navigate the "messy" and ill-structured nature of real-world problems, which rarely present clear pathways or single correct answers. Their growing capacity for logical reasoning and reflective thinking allows them to evaluate assumptions, justify decisions, and refine models iteratively. This aligns with broader trends in mathematics education, which emphasize higher-order thinking skills and complex problem-solving as essential competencies at this level (Cevikbas et al., 2024).

Furthermore, the development of mathematical thinking among learners is closely linked to their exposure to cognitively demanding tasks. Research indicates that secondary education provides a critical stage for enhancing analytical and mathematical thinking, as students are introduced to more advanced concepts and problem-solving strategies (Mafarja et al., 2026). Modelling tasks, which require synthesis and evaluation, naturally align with these developmental goals.

The integration of problem-based and inquiry-driven approaches in secondary classrooms further supports the implementation of modelling instruction. Studies on problem-based learning highlight its effectiveness in promoting deeper understanding and performance in mathematics, particularly when students are encouraged to explore real-world scenarios and construct their own solutions (Ayari et al., 2025). Such approaches mirror the principles of mathematical modelling, reinforcing its suitability for secondary education.

In addition, interdisciplinary learning opportunities are more prevalent at the secondary level, enabling students to apply mathematical concepts across domains such as science, engineering, and social studies. Research on STEM integration underscores the value of connecting mathematics to other disciplines through authentic tasks, which enhances both relevance and engagement (Ahr et al., 2026; Hallström & Schönborn, 2019). These interdisciplinary contexts provide a natural environment for modelling activities to thrive.

Technological advancements also play a significant role in supporting modelling at the secondary level. Digital tools, simulations, and AI-driven platforms enable students to explore complex systems, analyze data, and visualize results more effectively. Such technologies not only enhance conceptual understanding but also support decision-making processes within modelling tasks (He et al., 2025; Meylani, 2025). This technological integration further strengthens the case for implementing modelling instruction in secondary education.

Moreover, the emphasis on creativity and innovation in mathematics education aligns well with the objectives of modelling. Research highlights that open-ended and exploratory tasks foster mathematical creativity, allowing students to generate multiple solutions and approaches (Bicer, 2021). These characteristics are central to modelling, where flexibility and originality are key components of successful problem-solving.

The relevance of modelling in addressing contemporary and real-world challenges reinforces its importance in secondary education. In times of rapid societal and technological change, modelling provides learners with the tools to analyze complex issues and make informed decisions. Educational research conducted in disruptive contexts further emphasizes the need for adaptable and resilient learning approaches, with modelling serving as a critical framework for preparing students for uncertain futures (Siller et al., 2024).

Conclusion:

This systematic review highlights that effective mathematical modelling instruction is anchored in a coherent integration of three core dimensions: well-designed tasks, structured pedagogy, and comprehensive assessment systems. These elements function not as isolated components but as an interdependent triad that shapes meaningful learning experiences. The findings consistently demonstrate that task design serves as the foundation of modelling instruction, particularly when activities are authentic, open-ended, and grounded in real-world contexts. However, the effectiveness of these tasks is largely dependent on pedagogical approaches that support student inquiry, reasoning, and collaboration, as well as assessment systems that capture both the process and outcomes of learning.

The review also reveals a strong emphasis on pedagogical competence, particularly in the role of teachers as facilitators of learning. Effective modelling instruction requires educators to possess not only strong content knowledge but also the ability to guide students through complex and often ambiguous problem-solving processes. This includes diagnosing student difficulties, providing appropriate interventions, and fostering a classroom environment that values exploration and critical thinking. As such, professional development programs must prioritize the development of these competencies to ensure consistent and high-quality implementation of modelling practices.

Despite these strengths, the findings point to a notable imbalance in the literature, particularly in the limited focus on assessment systems. While modelling inherently involves complex cognitive and social processes, assessment practices often lag behind, with fewer studies addressing how to evaluate these dimensions effectively. This gap suggests the need for more robust, flexible, and process-oriented assessment frameworks that align with the nature of modelling tasks. Developing such frameworks will be essential for ensuring that assessment practices accurately reflect students' competencies and support continuous learning.

Another key insight from this review is the concentration of research at the secondary education level. This focus is largely attributed to the cognitive demands of the modelling cycle, which align with the developmental readiness of secondary learners. However, this emphasis also highlights a significant gap in research at the primary and tertiary levels. Expanding modelling instruction into primary education, with appropriate scaffolding and contextualization, could foster early development of problem-solving and critical thinking skills. Similarly, further exploration of modelling in higher education is needed, particularly in relation to advanced technologies and interdisciplinary applications.

Geographically, the distribution of studies indicates that research on mathematical modelling is concentrated in a limited number of countries, particularly in Europe and North America. This suggests a need for more diverse and context-specific investigations, especially in underrepresented regions. Expanding the global scope of research will not only enrich the theoretical understanding of modelling but also support the development of culturally relevant and contextually appropriate instructional practices.

Thus, this study contributes to the growing body of literature on mathematical modelling by synthesizing key dimensions, sub-dimensions, and trends in instructional frameworks. It underscores the importance of a balanced and integrated approach to teaching modelling, while also identifying critical gaps that warrant further investigation. Future research should focus on strengthening assessment practices, broadening institutional and geographic representation, and exploring innovative approaches that leverage technology and interdisciplinary learning. By addressing these areas, educators and researchers can work toward more effective, inclusive, and sustainable modelling instruction that prepares learners to navigate the complexities of the real world.

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