frontiers | Frontiers in Education

TYPE Review
PUBLISHED 19 February 2025
DOI 10.3389/feduc.2025.1467482

OPEN ACCESS

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RECEIVED 19 July 2024
ACCEPTED 04 February 2025
PUBLISHED 19 February 2025

CITATION
Markle J and McGarvey LM (2025) Research on task design in pre-service mathematics teacher education: a scoping review. *Front. Educ.* 10:1467482.
doi: 10.3389/feduc.2025.1467482

Research on task design in pre-service mathematics teacher education: a scoping review

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Tasks are central to every facet of mathematics education. In this scoping review, we bring together research focused on task design in the context of pre-service mathematics teacher education. We perform a qualitative content analysis of 112 peer-reviewed studies published between 2001 and 2023. The results of our review describe a diverse field of research, identify connections between works reflecting different demographics, aims, and methodological and theoretical commitments, and finally, through the application of the MEDSS task design action framework, foreground the different practical actions pre-service teaches must take to effectively design tasks. These include the practical actions of modifying, evaluating, developing, selecting, and sequencing (MEDSS) tasks. We believe the results of this study will be of value to mathematics teacher educators and researchers.

KEYWORDS

tasks, task design, pre-service teacher education, mathematics teacher education, scoping review pre-service teachers student teacher/s, teacher candidate, prospective teacher/s, teacher in training

1 Introduction

This scoping review was occasioned by our ongoing study of pre-service teachers' (PSTs) experiences of task design for the mathematics classroom. In that study, pre-service teachers engaged with a variety of digital tools and representations and the unit of analysis was their experiences of sequencing tasks, that is, grouping tasks intentionally in service of a pre-determined learning objective, which we see as one of the fundamental actions associated with task design.

In discussing the relationship between tasks and teaching, Sullivan et al. (2015) noted that tasks are that which "prompt activity which offers students opportunities to encounter mathematical concepts, ideas, and strategies," while teachers must "select, modify, design, redesign, sequence, implement, and evaluate the tasks" (p. 83). While the link between students' activity and tasks has always had a prominent place in mathematics education research, task design is a more recent and growing field of inquiry (Kieran et al., 2015).

During the course of our work on the study described above, we found the subset of task design research that involved PSTs specifically was rich and varied. So varied, in fact, that we wondered what, if anything, defined this subset of the literature. In particular, we often found it challenging to identify exactly what aspects of task design were being studied. The research question orienting our scoping review is: What characterizes research on task design with pre-service mathematics teachers?

In what follows, we will share details of our search and some key results. The latter include some general characteristics of the literature, a keyword network analysis that depicts some high-level connections between distinct bodies of work within the results, and a classification of each study according to the task design action on which it focuses. With respect to the latter, we drew on the literature (e.g., Watson and Ohtani, 2015) to parse task design into five essential actions—modifying, evaluating, developing, selecting, and sequencing—which we refer to as the MEDSS task design action framework.

Guided by the research question and this framework, our scoping review brings together research focused on task design in the context of pre-service mathematics teacher education. Our ultimate aim is to bring together a diverse body of research, reflecting a plurality of theoretical and methodological commitments, contexts, and mathematical topics, to inform mathematics teacher education practice and research.

2 Tasks and task design in mathematics education

Tasks are central to every facet of mathematics education. Despite this, describing what exactly constitutes a task has proved challenging. In terms of learners' engagement, tasks can be open-ended or closed, rich (Flewelling and Higginson, 2000), situated in real-world phenomena, procedurally and/or conceptually focused, and so-on. Further, they can be located in a curricular resource, such as a textbook, designed by teachers, or posed by students in the midst of mathematical activity.

Qualifying different kinds of tasks often begets additional dimensions of variation, as in the case of rich tasks, for example. In a well-known textbook for mathematics teacher education, Van de Walle et al. (2022) suggested that the character of these specific kind of tasks can be wide-ranging, in that they can be goal- or inquiry-oriented, presented in varied representations, require different amounts of time to complete, and so on. However, that the notion of task has been difficult to pin down does not necessarily reflect poor conceptualization. As can be inferred from the above, the character of a task is a function of the varied mathematical domains, learning environments, and pedagogical aims, for which a task can be purposed. In our study, we defined a task as any context (e.g., a textbook exercise, a teacher-designed problem, problems generated by students, etc.) in which individuals, including pre-and in-service teachers and students, are compelled to mathematical action.

2.1 Research on tasks and task design

That tasks are important to teaching and learning mathematics is evident in the prominence given to tasks and task design in recent research literature. A 2007 special issue of the Journal of Mathematics Teacher Education containing 21 articles on various aspects of tasks is a good example, as is the more recent ICMI study on task design in mathematics education (Watson and Ohtani, 2015). Over the last decade, research in task design has also widened to include a focus on the body's role in learning mathematics, as is shown in Alberto et al.'s (2022) review of the embodied design literature.

This study focuses on the nature of research on task design with pre-service teachers, which is a subset of the larger research program described above. To this end, we developed and applied the MEDSS Task Design Actions Framework (MEDSS-TDA), which specifies task design as entailing the actions of modifying, evaluating, developing, selecting, and sequencing (MEDSS) tasks for the mathematics classroom. As noted by Sullivan et al. (2015), these will be actions familiar to classroom mathematics teachers. Modifying tasks is an essential and frequently used skill that involves adapting, revising, or further refining an initial problem or problem set to achieve pedagogical goals, such as when teachers alter a textbook question or adapt a task to meet a curricular outcome. Evaluating tasks is context-dependent and involves analyzing a task against a predetermined set of criteria. This could include, for example, evaluating a task's alignment with curriculum outcomes or other characteristics of a task, such as whether it has variable entry and exit points. Developing tasks involves creating new problems or activities without an initial task as a starting point. This distinction sets it apart from modifying actions, as developing pertains to situations in which teachers do not begin with a pre-formatted task, but may start with a context, information, or vignette, such as in the problem posing literature. Selecting entails choosing a specific task(s) for an explicitly stated purpose, such as to meet a curricular outcome or encourage a particular kind of mathematical activity, and sequencing involves linking multiple tasks in service of an explicitly stated purpose.

Our scoping review of the literature is not so much oriented around gaps in research, since there is clearly a rich tradition of tasks and task design research in the field of mathematics education. Rather, we seek to make explicit the practical actions involved in task design in order to position these diverse literatures in conversation with each other. Ultimately, we hope this serves to elicit new directions and insights in the field.

3 Methodology

3.1 Literature search strategy and inclusion criteria

Following guidance provided by Tricco et al. (2018), we adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) to conduct our literature search. For our search, we identified pre-service teachers as the relevant population, task design in K-12 mathematics as the relevant concept, and teacher training as the relevant context. Table 1 provides lists of associated keyword search terms for each of the population, concept, and context constructs. These keywords were generated in collaboration with university librarians. Table 2 provides the representative search strategy. Searches on seven databases were conducted on November 27, 2023, by two university librarians.

A total of 5,746 studies were generated from those searches and 1,002 duplicate studies were removed prior to screening, leaving 4,744 studies. The authors and four research assistants used the exclusion criteria described in Table 3 and the protocol developed by Polanin (2020) for systematic reviews to screen the 4,744 studies using abstracts and titles.

Prior to this stage of screening, two rounds of inter-rater reliability testing occurred on tranches of 25 randomly selected studies. All six individuals screened each study anonymously and subsequently discussed their decisions as a group for each tranche of 25 abstracts. As a group, we determined that we had obtained a sufficient level of consensus after completing the second round of testing. Subsequently, we applied the exclusion criteria found in Table 3 to screen abstracts and titles, and removed 4,507 studies. We screened in tranches of 400 abstracts and met to ensure we maintained satisfactory agreement. To this end, Cohen's Kappa, a measure of inter-rater reliability, indicated moderate agreement for this stage of the screening. At these meetings, we (the authors) would resolve any screening conflicts that had occurred and discuss our decision-making with the rest of the team.

The two authors then used the exclusion criteria listed in Table 3 to screen the full texts of the remaining 237 studies and also obtained moderate agreement (Cohen's Kappa = 0.51). The two authors met to resolve all issues by reviewing the inclusion/exclusion criteria for each conflicting study. Although we had well-defined inclusion and exclusion criteria, several studies required deliberation. For example, a study might involve pre-service teachers and aspects of task design, but have a research focus on some other aspect, such as teacher identity or proficiency with technology. In these cases, we only included studies on which we reached full consensus. A total of 122 full text studies were excluded during this stage of the screening and an additional 3 duplicate records were identified and removed. A total of 112 studies remained and are included in our review. Figure 1 shows the selection procedure in its entirety.

TABLE 1 Keywords.

Population Pre-service teachers	Student teacher/s, teacher candidate, prospective teacher/s, teacher in training, Pre-service teacher/s, beginning teachers, Education interns, education majors
Concept Mathematics task design	Math, mathematics, mathematical, maths, numeracy, Applied mathematics, Probability, Decimals, Polynomials, Mathematical problems, Set theory, Euclidean space, Nonlinear equations, Parabolas, Polyhedra, Calculus, Number systems, Mathematical functions, Trigonometry, Polygons, Combinatorics, Geometry, Addition and subtraction, Fractions, Number theory, Linear equations, Mathematics, Metric system, Multiplication and division, Tetrahedra, Algebra task/s, design, task design, curriculum design, problem design, instructional design, task analysis, didactics, didactic variable, variation, variation theory, variation pedagogy, variation theory of learning, theory of variation, noticing, teacher noticing, lesson study, learning study, modeling, problem posing, activity/ies
Context Teacher training	Teacher training, teacher education, pre-service teacher education, student teaching

TABLE 2 A representative search.

Population Pre-service teachers	(teacher* N4 (student OR candidate OR prospective OR training OR preservice OR beginning)) OR student* AND ("education intern*" OR "education major*")
Concept Mathematics task design	(arithmetic OR math* OR numer* OR number* OR equation* OR algebra OR geometry OR calculus OR trigonometry OR addition OR subtraction OR fraction* OR multiplication OR division OR probability) N3 ((design* N2 (task* or curricul* or problem* or instructional or lesson)) or didactic* or pedagog* or activity or activities or "problem posing" or "lesson plan*")
Context Teacher training	"teacher education" OR "teacher training" OR "student teaching"

3.2 Data analysis

Data analysis consisted of three stages. In the first stage of analysis, the authors and one of the research assistants collected data on the general characteristics of each study. This included the journal, publication year, characteristics of the method and other study design considerations, the inclusion of certain keywords (e.g., task design), theoretical and methodological approaches, and others. Our intent with this first stage is to provide a high-level overview of the kinds of research on task design in pre-service teacher education, including the grade level, mathematical topic, and pedagogical focus.

In the second stage of analysis, we performed a keyword co-occurrence mapping to investigate the interrelationships among the frameworks and vocabulary used in the diverse fields of task design research. We utilized VOSviewer, a tool designed for creating and visualizing bibliometric networks, including keyword, author, and citation co-occurrences. Specifically, we focused on the keyword co-occurrence component to generate the map.

The set of search terms for our study, shown in Table 2, included various terms related to the concept of mathematics task design. These terms were selected to reflect the wide range of topics in mathematics (e.g., algebra, geometry, probability), diverse approaches to tasks (e.g., problem posing, inquiry-based tasks, cognitive demand), and relevant pedagogical theories (e.g., variation theory, teacher noticing). While these topics all relate to mathematics task design, the literature

TABLE 3 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
1. Focuses on work conducted on or with pre-service teachers	1. Does not focus on work conducted on or with pre-service teachers
2. Studies meet our definition of task design	2. Studies do not focus on task design
3. Focus is on pre-service teachers engaged in task design for the purposes of teaching K-12 mathematics	3. Focus is on other aspects of pre-service teacher education, such as creativity, identity, etc.
4. Peer-reviewed empirical studies	4. Theoretical papers, books, book reviews, etc.
5. Focus on K-12 mathematics	5. Focus is on another subject or on mathematics outside the K-12 grade band (e.g., undergraduate mathematics)
6. Studies published prior to the search date (November 27, 2023)	6. Studies published outside that date
7. Studies indexed in ERIC, Education Research Complete, British Education Index, Australian Education Index, Education Database, CBCA: Social Sciences, and PsychInfo	7. Studies not indexed in at least one of these databases
8. Published in English	8. Not published in English

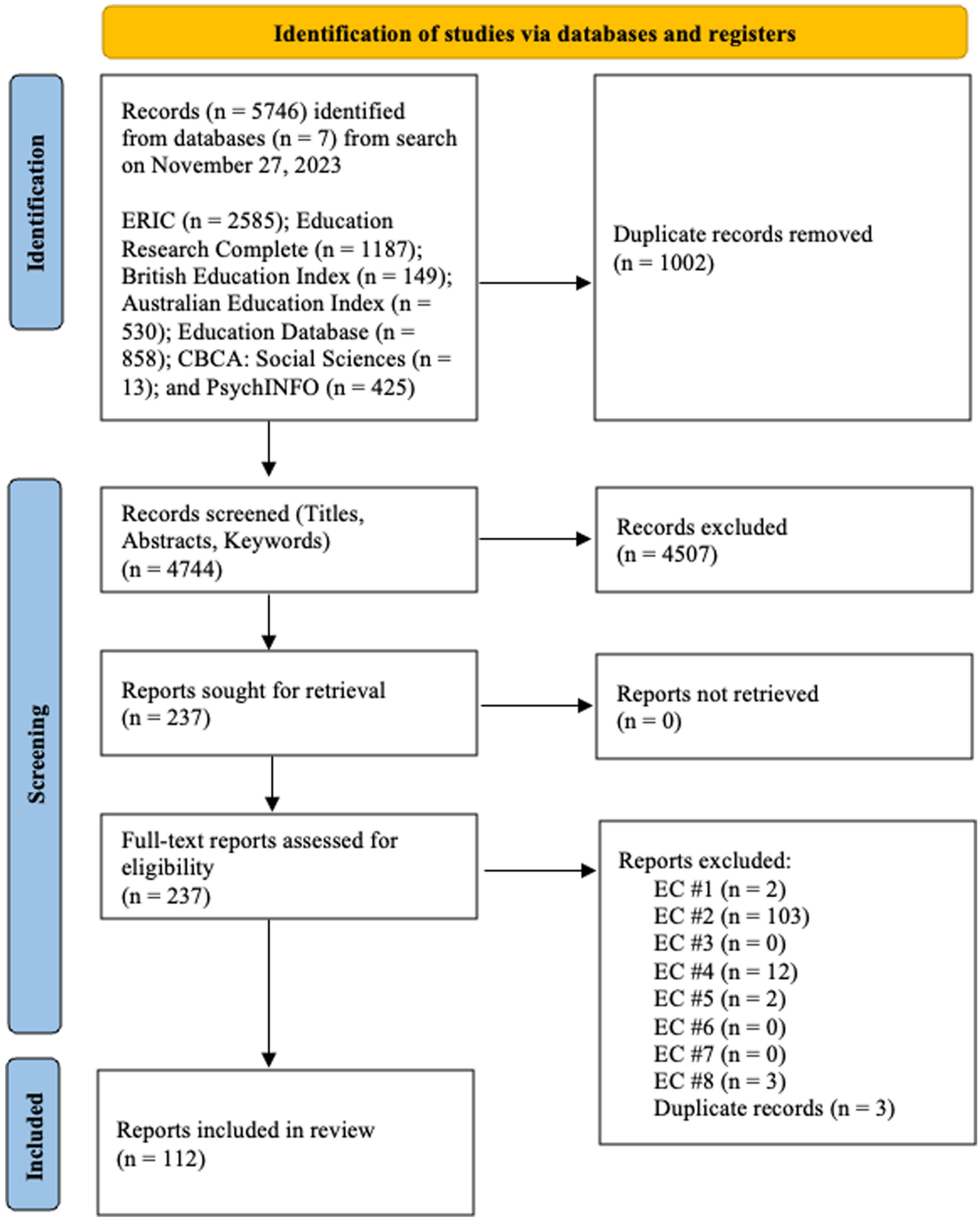

FIGURE 1
The preferred reporting for items for systematics reviews and meta-analyses (PRISMA) screening procedure.

employs different descriptors and theoretical frameworks across specific mathematical areas and broader STEM subjects.

Our objective was to identify the interrelationships between these bodies of literature and determine whether they were "speaking" to one another as a way to characterize the field of study. To achieve this, we compiled keywords from both the author-assigned keywords and index terms in the articles. Additionally, we extracted potential keywords from the abstracts of the included studies. Given the diverse keywords, we encountered various forms of linguistic variation, including synonyms, plural and singular forms, gerund (−ing) variations, and related phrases that expressed similar concepts (e.g., "cognitive demand," "cognitively demanding tasks," "cognitive demand task"). To strengthen the network and reduce redundancy, we consolidated related terms by selecting one representative keyword (e.g., "cognitive demand") for each set of synonyms or variations.

Finally, we prepared a CSV file containing the bibliographic information for each article and the consolidated representative keywords. This file was uploaded to VOSviewer to generate a keyword co-occurrence network map.

In the third and final stage, the two authors used qualitative content analysis to characterize the nature of task design activities in each of the studies. We coded these activities as modifying, evaluating, developing, selecting, and/or sequencing. Hsieh and Shannon (2005) defined qualitative content analysis as the "subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (p. 1278). The authors conducted a close reading of the included studies to categorize them according to the MEDSS-TDA framework presented in Table 4. To obtain a code for one of the categories, the study needed to explicitly identify a task design action as a research focus. After coding individually, the authors met to discuss each paper and their respective codes in order to establish a final categorization. This approach was guided mostly by what Hsieh and Shannon (2005) denoted as directed content analysis, in which "researchers begin by identifying key concepts or variables as initial coding categories" in order to say something about a "phenomenon that is incomplete or would benefit from further description" (p. 1281). We intend our application of the MEDSS-TDA framework as a means of attending to the latter and putting the diverse literatures represented in the study results into conversation with each other.

4 Results

4.1 Stage 1: general characteristics of the literature

The results of our scoping review reflect a broad geographic interest in studying task design in pre-service teacher education. A total of 20 different countries are represented in the results, with the highest frequency of studies occurring in the USA (32), Turkey (17), Spain (6), and Ireland (5). The studies were approximately evenly distributed across elementary (41) and secondary (57) mathematics teacher education contexts, with a handful of studies (7) including both. The results also reflected study of a diversity of mathematical topics and domains. Some studies targeted specific topics, including algebra (23), number (18), and geometry (13), while others focused on pedagogical practices and allowed for tasks from a variety of topics (41). A total of 26 studies explicitly identified classroom experience (i.e., practicum) as part of the study design and 7 included in-service teachers as participants.

Some bodies of literature in mathematics education are well-represented in the results. For example, of the 77 studies with a well-defined pedagogical focus, 32 of those located themselves within the problem-posing literature, which makes sense given that this body of literature is oriented around modifying and developing mathematics tasks. In terms of methodology, most of the studies (83) were explicitly identified as qualitative, and a variety of approaches were represented to differing extents. For example, content analysis and case study were frequently used, while only five studies specified lesson study as a methodology, which was lower than we anticipated. Finally, as Figure 2 shows, our results include studies from over more than two decades. We note that the distribution of their occurrence underscores the relevance of this study: over half (57) of the included studies have been published since 2019, inclusive, and 6 of the 7 articles that included "task design" as a keyword were also published in those years.

TABLE 4 MEDSS task design action framework.

Action	Possible indicators
Modifying	Altering existing resources, such as textbooks, pre-made tasks, etc., to suit a specific purpose
Evaluating	Addressing affordances of a task, including the cognitive demand of a task, alignment with learning objectives, etc. Could include evaluating resources, such as textbooks.
Developing	Creating new tasks (e.g., mathematical modeling to investigate real-world phenomena, free problem posing)
Selecting	Choosing tasks for specific purposes, such as to attend to domain-specific understandings, mathematical processes, extra-mathematical considerations, student population, etc.
Sequencing	Connecting two or more tasks for a stated purpose (e.g., to address a learning objective)

4.2 Stage 2: keyword co-occurrence network map

Using VOSviewer, we generated a keyword co-occurrence network map to examine the relationships among keywords in mathematics task design research (see Figure 3). VOSviewer is a bibliometric tool that visualizes networks such as co-occurrences of keywords, authors, or citations. In this map:

- Node size (bubble size) represents the frequency of a keyword's appearance.
- Edge thickness (lines connecting bubbles) indicates how frequently two keywords co-occur within the same study. Thicker lines reflect stronger connections.
- Proximity between bubbles reflects the relatedness of keywords—closer bubbles indicate higher co-occurrence.
- Clusters are identified based on VOSviewer's clustering algorithm, which maximizes the density of connections within a group of nodes while minimizing connections between groups. Keywords within the same cluster have higher co-occurrence frequencies, suggesting stronger thematic relationships.

To maintain the coherence of the network and ensure meaningful clustering, we set the minimum occurrence threshold to three. This excluded isolated keywords with low frequency, which could have disrupted the structure and interpretability of the clusters. Additionally, we excluded keywords related to the population (e.g., pre-service teachers) and context (e.g., teacher education), as their frequent occurrence would have dominated the network. This exclusion allowed the focus to remain on the relationships surrounding task design and ensured that the resulting clusters reflected the thematic content of the studies rather than their contextual details.

The resulting network includes 31 keywords, 146 links, and 4 distinct clusters (color-coded), with a co-occurrence weight (i.e., link strength) of 270. On average, each link in the network has a co-occurrence strength of approximately 1.85 (i.e., 270 ÷ 146), meaning the relationships are generally weak but consistent rather than dominated by very strong pairings. Each cluster is characterized by its dominant themes, as summarized below:

4.2.1 Cluster 1 (red): task design

The red cluster, anchored by the keyword task design, includes terms such as cognitive demand, modeling, mathematical content, design principles, teacher knowledge, algebra, and dynamic geometry. This cluster highlights the diverse aspects of designing tasks and

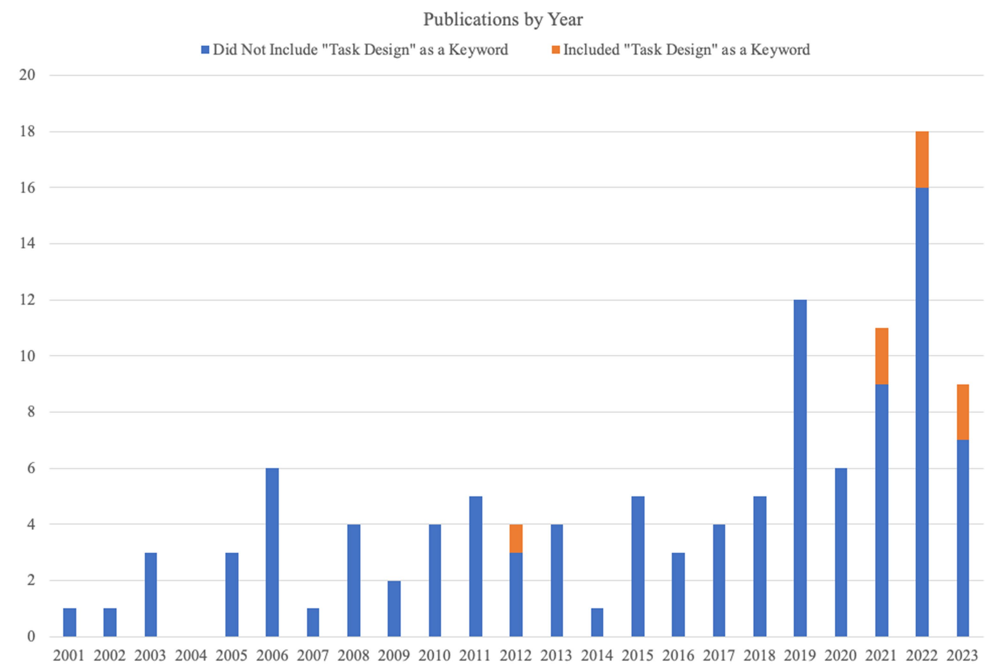

FIGURE 2
Included full text publications by year. The number of publications that used "task design" as a keyword is shown in orange.

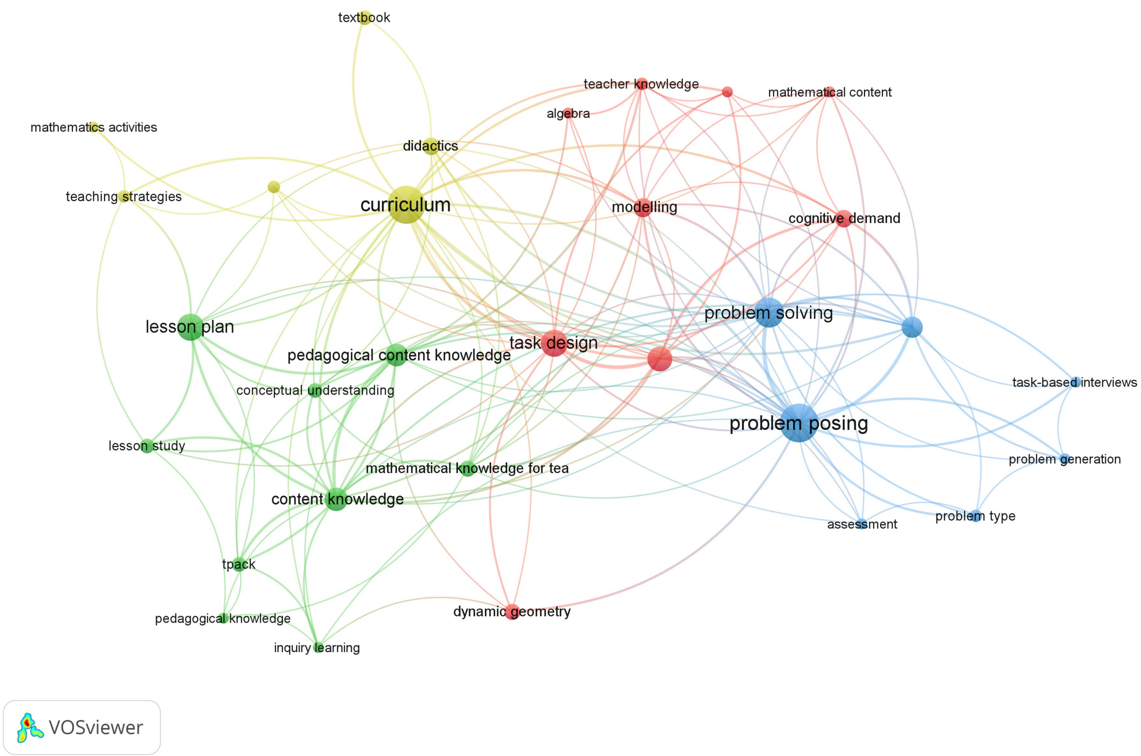

FIGURE 3
A keyword co-occurrence network map depicting relationships among keywords used in the included articles.

specific mathematical content areas like algebra and dynamic geometry. The inclusion of teacher knowledge and design principles emphasizes the role of educators' expertise in creating tasks that support meaningful learning.

4.2.2 Cluster 2 (green): pedagogical knowledge

The green cluster focuses on pedagogical frameworks and teacher knowledge, with prominent keywords including pedagogical content knowledge (PCK), conceptual understanding, lesson plan, inquiry learning, lesson study, TPACK, mathematical knowledge for teaching (MKT), and content knowledge. This cluster underscores the importance of both content knowledge and pedagogical approaches to effective mathematics task design. The emphasis on lesson plan and lesson study also highlights the practical components of implementing task design within classrooms.

4.2.3 Cluster 3 (blue): problem-centered approaches in mathematics

The blue cluster centers on the use of problems as tools for both teaching and assessment. Dominant keywords include problem posing, problem solving, problem generation, mathematics problems, assessment, problem type, and task-based interviews. This cluster illustrates the critical role of problems in fostering mathematical thinking, inquiry, and understanding. It also highlights the dual purpose of tasks: as a teaching strategy and as a method for assessing students' problem-solving abilities.

4.2.4 Cluster 4 (yellow): curriculum

The yellow cluster focuses on the broader curricular and instructional contexts of task design. Key keywords include curriculum, didactics, teaching strategies, textbook, realistic mathematics education, and mathematics activities. This cluster indicates a focus on how curriculum frameworks, instructional strategies, and resources like textbooks influence mathematics task design and its implementation in classrooms. The presence of realistic mathematics education connects to research emphasizing real-world contexts in mathematics learning.

The keyword "task design" holds a central position within the network map, which is expected given its role as the focus of this scoping review. To further analyze its significance and connections, we isolated all keywords that directly co-occur with task design in Figure 4. This visualization highlights the specific relationships between task design and other keywords, offering insight into its function as both a thematic focal point and a connector across clusters.

In this focused map, the two closest keywords to task design are "mathematical task" and "pedagogical content knowledge." Their close proximity indicates a strong co-occurrence, suggesting that studies frequently explore task design alongside discussions of the nature of mathematical tasks and the role of teachers' pedagogical content knowledge (PCK). This reinforces the dual focus in the literature on both the content of tasks and the knowledge required to design and implement them effectively.

Interestingly, while task design serves as a central hub, it is spaced from several other keywords, even within its own cluster (red). This suggests that while the term co-occurs with other concepts such as "cognitive demand," "design principles," and "dynamic geometry," the frequency of these co-occurrences is not particularly high. Rather, task design acts as a thematic anchor that connects related but somewhat distinct areas of research.

Notably, task design connects across all three of the other clusters (green, blue, and yellow), with links to "pedagogical content knowledge" (green), "problem solving" and "problem posing" (blue), and "curriculum" (yellow). These cross-cluster connections, though ranging from weak to moderate in strength, reflect the interdisciplinary nature of mathematics task design research. For example:

- In the green cluster, connections to "pedagogical content knowledge" and "content knowledge" highlight the role of teacher knowledge in effective task design.
- In the blue cluster, links to "problem solving" and "problem posing" emphasize task design's connection to problem-centered instructional approaches.

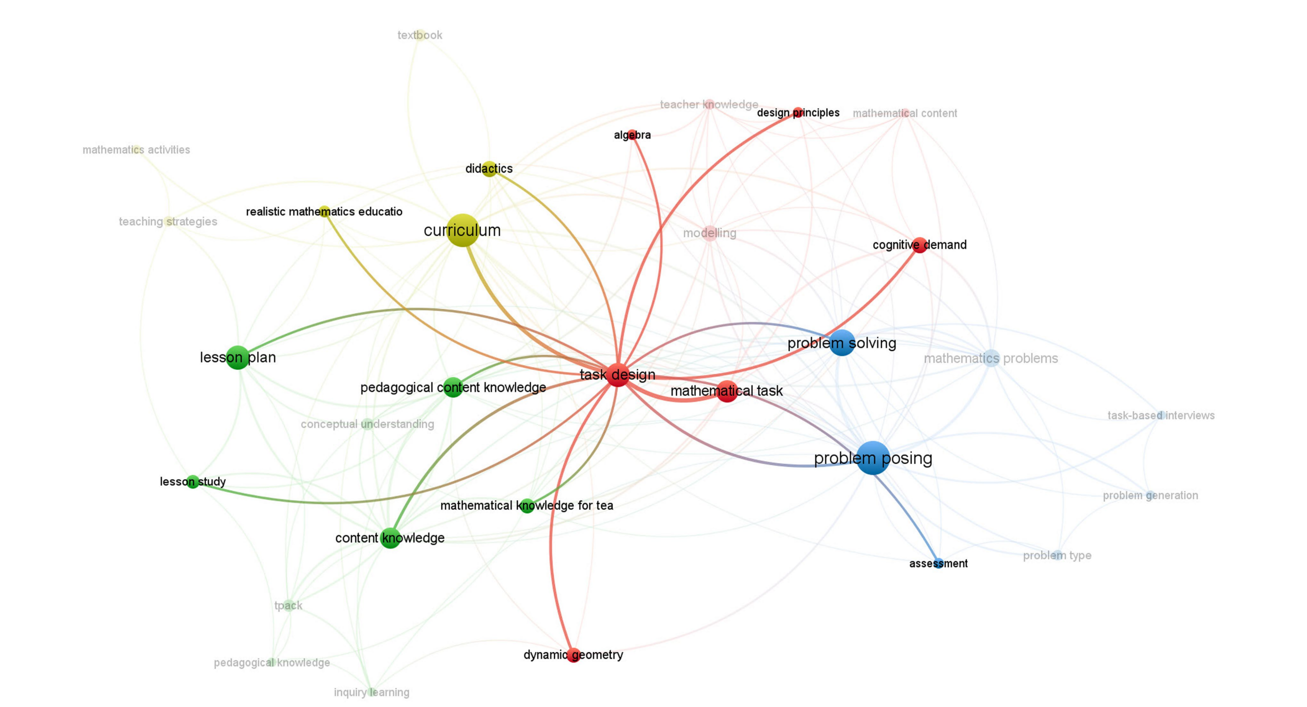

FIGURE 4
A keyword co-occurrence network map depicting relationships among keywords and the key word "task design".

- In the yellow cluster, the connection to "curriculum" reflects how task design intersects with broader curricular frameworks and instructional strategies.

Overall, the centrality of task design within the network demonstrates its integrative role in bridging multiple themes and perspectives. While the connections within its own cluster are somewhat spaced, its cross-cluster links suggest that task design serves as a unifying concept, drawing together research on pedagogy, problem-solving, and curriculum design. However, the relatively moderate co-occurrence strengths also indicate opportunities for greater integration and dialog among these related but still somewhat siloed areas of research.

4.3 Stage 3: specific characteristics of task design activity

Using the MEDSS-TDA framework described in Table 4 and qualitative content analysis, we categorized each study as Modifying, Evaluating, Developing, Selecting, and/or Sequencing. We visualized the data using an upset plot (Figure 5). An upset plot serves as an alternative to a Venn diagram but is more structured and scalable, making it well-suited for visualizing datasets with multiple overlapping categories. In this plot, the horizontal bars show the frequency of studies that include a specific task design action, while the vertical bars indicate the combinations of actions occurring within studies.

The frequencies for each task design action, read horizontally, highlight the following: Developing tasks was the most frequent action, appearing in over half of the studies (61 studies; 55%). This was followed by modifying tasks, which were observed in 33 studies (30%), and evaluating tasks, appearing in 27 studies (24%). In contrast, the actions of selecting tasks (11 studies; 10%) and sequencing tasks (1 study; <1%) were far less frequent, indicating limited research attention to these aspects of task design. Of the 112 studies in the scoping review, 18 studies did not include explicit or discernible task design actions, or the actions were unclear. As a result, the graph represents 94 out of 112 studies.

When examining combinations of task design actions (read vertically), a significant portion of the studies focused on a single task design action (62 studies; 55%). Of these, the most common was developing tasks alone (36 studies), followed by evaluating tasks alone (15 studies) and modifying tasks alone (11 studies). Beyond single actions, combinations such as modifying and developing tasks (13 studies) were observed, but the co-occurrence of three or more actions dropped off sharply.

This predominance of single-task design actions may reflect the challenges associated with conducting research in preservice teacher education contexts, where studies often narrow their focus to a single, manageable aspect of task design. Despite this focus, it is reasonable to assume—or hope—that preservice teachers are provided with opportunities to engage in all five types of task design actions as part of their broader education and preparation.

Overall, the upset plot highlights a clear emphasis on developing, modifying, and evaluating tasks within the literature, with limited

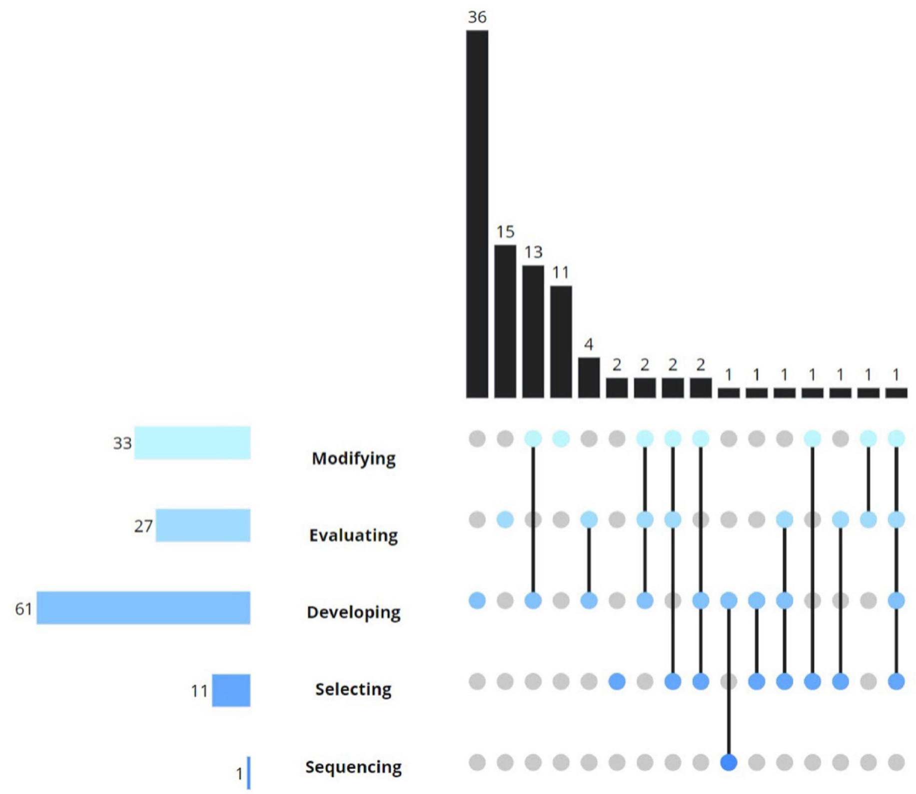

FIGURE 5
An upset plot depicting the number of studies categorized by task design action. The horizontal bars show the frequency of studies that include a specific action, while the vertical bars indicate the combinations of actions occurring within studies.

exploration of selecting and sequencing. This imbalance points to potential gaps in the research and opportunities for future studies to examine underrepresented task design actions more comprehensively.

A majority of the studies were categorized as involving Modifying (33), Analyzing (27), and/or Developing (61). A minority of studies were coded as involving Selecting (11) and/or Sequencing (1). We noted that while sequencing tasks might be implicit in many of the approaches represented in this review (e.g., problem posing), only a single study identified it as an explicit focus in the research design. A total of 18 studies were not categorized because they did not explicitly identify one of the MEDSS-TDA framework actions. Finally, we found that over half of the included studies (64) identified a single task design action as a focus, 20 percent of studies (22) identified two actions, seven included three actions, and one included four of the five actions.

Our scoping review makes three important contributions. First, it presents an overview of a diverse field of research focused on task design in pre-service teacher education. Second, our network analysis makes connections between works reflecting different demographics, aims, and methodological and theoretical commitments. Finally, applying the MEDSS-TDA framework to this diverse collection afforded opportunities to foreground the different practical actions pre-service teachers must take to effectively design tasks. In this section, we first draw on the literature results to discuss each action from the MEDSS-TDA framework in turn. Next, we focus on particular subsets of the literature results through the lens of the MEDSS-TDA framework. In doing so, we aim to demonstrate that an explicit focus on distinct design actions is one means of drawing meaningful connections between different literatures.

4.4 Modifying

Rarely do teachers create tasks without starting with an initial resource or context. Modifying tasks is an essential and frequently used skill that involves adapting, revising, or further refining an initial problem or problem set to achieve pedagogical goals. In this literature, the starting points for modifying tasks included textbook questions (e.g., Chapman, 2007), instructor-given problem sets (e.g., Stickles, 2011), specific problems, such as the Billiard Task (Koichu and Kontorovich, 2013), the NIM game (Baumanns and Rott, 2022b), and the Handshake Problem (Erkan and Kar, 2022), or creating story problems from integer equations (e.g., Wessman-Enzinger and Tobias, 2022). The goals for modifying tasks also varied across the studies, such as aligning tasks with curriculum expectations (e.g., Paolucci and Wessels, 2017), making the tasks more accessible and relevant to students (e.g., Harper et al., 2021), or helping PSTs to gain an understanding of how tasks promote mathematical reasoning (Oliveira and Henriques, 2021). These examples illustrate the diverse approaches and objectives in modifying actions, highlighting its critical role in preservice teacher education.

4.5 Evaluating

The capability to evaluate tasks is integral to being an effective mathematics teacher and permeates much of mathematics classroom practice. This might manifest as identifying the underlying mathematical structure of a task (as in the semi-structure problem posing literature, discussed in more detail below), determining whether a task is open or closed, and so on. It is unsurprising that this subset of the literature reflects the diversity inherent in mathematics education research. Osana et al. (2006) asked PSTs to evaluate and classify tasks according to the perceived levels of cognitive demand and emphasized the need for adequate content knowledge to do so. Navarro and Céspedes (2022) used didactic suitability theory to study an intervention aimed to support PSTs in evaluating textbook tasks. They identified the importance of a resource to guide PSTs analysis and reflection in supporting their professional development. Parrish et al. (2023) also utilized a framework grounded in the curricular noticing literature (Dietiker et al., 2018) to study how PSTs launched cognitively demanding tasks. A common theme across this subset of the results was the importance of well-structured frameworks for supporting PSTs' developing competence.

4.6 Developing

Developing tasks involves creating new problems or activities without an initial task as a starting point. This distinction sets developing apart from modifying actions, as developing tasks do not begin with a pre-formatted problem or task but may start with a context, information, or vignette where tasks were not previously posed. In several studies, it was difficult to determine the specific information PSTs began with, so we relied on the authors' descriptions, such as asking PSTs to "create," "develop," "pose," or "design" problems. In other studies, PSTs were asked to develop tasks in technology environments for geometry (e.g., Gulkilik, 2023) or coding (e.g., Broley et al., 2023), from real-world data sets (e.g., Chick and Pierce, 2012), or from children's literature (e.g., Purdum-Cassidy et al., 2015). The types of tasks developed were usually designed for the mathematics classroom, but several studies focused on alternative or creative forms such as mathematics comics (Putra and Aljarrah, 2021), letter writing to individual students (Crespo, 2003; Leavy and Hourigan, 2022), and interdisciplinary activities with science (An, 2017) and dance (An et al., 2019). These diverse approaches highlight the creativity and adaptability required in developing tasks, ensuring they are engaging and relevant to students' varied learning experiences.

4.7 Selecting

The action of Selecting entails choosing a specific task(s) for an explicitly stated purpose. This could include practices familiar to the typical mathematics teacher education experience, such as when PSTs learn to discern what it means for a task to be a good one (e.g., rich tasks, as discussed above). Kartal et al. (2020), for example, sought to understand how PSTs identified problem-solving tasks, which are those that "promote reasoning and problem solving by allowing students access to the mathematics through multiple entry points, including the use of different representations and tools, and fostering the solving of problems through varied solution strategies" (p. 86). They noted that PSTs struggled to identify key features of such tasks and concluded that "realizing what [PST] s understand and where they struggle to identify appropriate problem-solving tasks" (p. 107) is key to furthering this area of research.

Clearly, the action of selecting a problem-solving task necessarily entails the action of evaluating, and so we were unsurprised to see these two actions co-occur frequently (see Figure 5). However, of the

11 studies we categorized as explicitly attending to the action of Selecting, we found a wide variety of considerations and contexts. Broley et al. (2023), for example, focused on the challenges PSTs faced when choosing coding tasks in collaboration with practicing teachers. Cardoso et al. (2023) observed PSTs' development of pedagogical content knowledge in the context of lesson study, specifically through analyzing the types of tasks PSTs selected for inclusion in their lesson. Despite the diversity, we found that this subset of the literature was oriented by supporting PSTs in evaluating and selecting tasks according to the criteria for rich tasks found in Van de Walle et al. (2022) and other sources.

4.8 Sequencing

Sequencing involves linking multiple tasks in service of an explicitly stated purpose. For example, researchers and educators who draw on the principles of variation theory will recognize this action in the use of systematic variation between tasks, in which a set (or sequence) of tasks is carefully designed to draw learners' attention to an intended object of learning (Kullberg et al., 2024). Effectively sequencing tasks is clearly important to teaching and learning mathematics. However, in this review of research on task design in pre-service mathematics teacher education, we found only one study explicitly identified sequencing tasks as a research focus. Pincheira and Alsina (2022) studied how PSTs selected sequences of tasks in the context of a larger study of specialized content knowledge and mathematics knowledge for teaching. We echo Pincheira and Alsina (2022) and others (e.g., Jones and Pepin, 2016) in identifying the design of task sequences as integral to teaching mathematics. We suggest that future research make this an explicit study focus.

5 Discussion

Applying the MEDSS-TDA framework to the diverse collection of studies included in this review afforded opportunities to both draw important distinctions within bodies of work and make connections across ostensibly different fields of mathematics education research. In this section, we focus on discussing the MEDSS-TDA framework in the context of the literature from our study results related to problem posing, which accounted for approximately a quarter of the included studies. Our aim is to show how a focus on task design actions might foreground phenomena that are implicit within this subset of our results and to make connections between this literature and other bodies of research.

Problem posing has been defined as the creation and reformulation of mathematical problems (Silver, 1994). Moreover, this can occur in problem situations that have been characterized as structured, semi-structured, and free (Stoyanova and Ellerton, 1996). Given such broad constraints and the possibility of a wide range of mathematical and pedagogical aims, the character of problem posing situations can vary considerably, and in that sense, reflects the diverse literature on task design in math education research. However, in a recent review of the problem posing literature, Baumanns and Rott (2022a) noted that while it is a prominent focus in mathematics education, the fact is that the term problem posing is "used to cover numerous activities that differ considerably from each other" (p. 28). We see this as a significant issue given the prominence of studies that adopt a problem posing framework in task design research in mathematics teacher education.

In this respect, we echo the concerns of others. In their review of problem posing in primary mathematics teacher education, Osana and Pelczer (2015) identified the "need [for pre-service teachers] to develop an ability to pose and adapt problems with specific pedagogical purposes in mind" (p. 489), but also noted that pre-service teachers experience difficulties in problem posing for a variety of reasons. They suggested that one step toward structuring research on problem posing in teacher education and its use in the classroom with pre-service teachers would be to use a consistent definition specific to those fields, namely that problem posing be considered the "act of formulating a new task or situation, or modifying an existing one, with a specific mathematical learning objective and a targeted pedagogical purpose in mind" (Osana and Pelczer, 2015, p. 486).

Our approach aligns well with the definition formulated by Osana and Pelczer (2015). In contrast to Stoyanova and Ellerton's (1996) taxonomy, Osana and Pelczer (2015) foregrounded the actions of teachers (e.g., the acts of formulating, adapting, modifying, etc.), rather than the static affordances of a given problem situation. This is not to say that the distinction between structured, semi-structured, and free problem situations is not critically important, only that taken on its own, the practical actions of teachers are potentially obscured. Similarly, Baumanns and Rott (2022a) focused on what they call manifestations, or the particular enactments of problem posing activity. In doing so, they reframed, for example, semi-structured problem posing as generation, which is characterized as the specific action of adding conditions to the problem situation.

As noted above, a total of 32 studies in our review used problem posing as a keyword and/or were identified as situated in that literature. When we applied our framework to these studies, we found that a majority of them (24) were categorized exclusively as Modifying (5), Developing (9), or as Modifying and Developing (10). We argue these categorizations align well with and complement the existing problem posing literature, namely that problem situations can be structured, free, and semi-structured, respectively. For example, Lavy and Bershadsky (2003) and Lavy and Shriki (2003) are exemplars of studies that we categorized exclusively as modifying. Each is oriented by well-structured problems and a clearly defined pedagogical strategy.

At the other end of the spectrum, some researchers have utilized free problem posing situations to support pre-service teachers in developing their own tasks. Leavy and Hourigan (2022) asked primary pre-service teachers to create a math problem aligned with a chosen learning outcome. They focused on discerning the affordances and constraints of a task and noted that PSTs included elements that were both desirable (e.g., opportunities for multiple solutions) and limiting (e.g., no or infinite possible solutions) in their tasks. In the broader context of task design, Leavy and Hourigan (2022) suggested that a more direct connection between PSTs' task design and implementing the tasks in classrooms would be beneficial to PSTs. On this note, only 26 of the studies included in this review included practicum experience in the research design, and only one of those (Crespo, 2003) were part of the subset of literature focused on problem posing.

We also coded a number of studies as both Modifying + Developing, and we found this body of work shared affinities with the literature associated with semi-structured problem posing. Baumanns and Rott (2022a) described semi-structured situations as those in which the "poser is invited to explore the structure of an open situation by using mathematical knowledge, skills, and concepts of previous mathematical experiences" (p. 31). For example, Ellerton (2013) used problem posing to help PSTs understand the underlying mathematical structure of pre-given tasks (e.g., the handshake problem). In another study, Wessman-Enzinger and Tobias (2022) used number sentences as a constraint for PSTs to pose story problems related to temperature, which required them to draw on pre-existing conceptual understandings of integers and arithmetic operations.

The papers we discuss in this section underscore how integral problem posing, in all of its guises, is to the task design process. However, the practical actions required to effectively pose problems in the mathematics classroom is sometimes unclear in this research. We recognize this is in part due to the rich and varied contexts taken up by researchers and educators in this field, and we argue that explicitly linking these contexts to task design actions is one means of foregrounding these practical actions.

We are certainly not the first to propose linking problem posing to classroom actions. Ellerton (2013), for example, offered the Active Learning Framework, which "situates active problem posing in mathematics classroom in the context of mathematics teaching and learning" (p. 97). This approach distinguished between classroom actions (e.g., teachers modeling a procedure, students solving problems, posing problems, etc.) and specific student actions (e.g., observing, imitating, etc.). Ellerton (2013) noted that in the context of pre-service teacher education, students had only experienced a "truncated" version of the model, one that omitted the opportunity to pose problems (p. 99).

Somewhat in contrast to Ellerton (2013) framework, which is linearly structured along a spectrum of teacher and student involvement, Baumanns and Rott (2022b) offered a descriptive phase model, in which the problem poser may move freely between actions (e.g., evaluation, variation, generation, etc.). In this respect, our approach is similar to that of Baumanns and Rott (2022b), in that the task design actions can be used in any sequence. Using problem posing as an example, we see making these task design actions explicit as a means of enabling researchers to make critical distinctions in their units of analysis. Put another way, it foregrounds how might problem posing be used to develop very different skills integral to mathematics teaching and learning.

We also see a focus on task design actions as a means of making connections across seemingly disparate bodies of literature. Chapman (2007), which we categorized as Modifying + Evaluating + Developing, exemplifies the potential of this approach. In that study, the practical actions underlying both the capabilities required to effectively pose problems and posing problems in different problem situations are explicit. PSTs were asked to create new word problems, pose new word problems based on existing tasks, and analyze word problems in textbooks. Although Chapman (2007) was not explicitly situated in problem posing, its affinities with that literature is clear. For example, Paolucci and Wessels (2017), which we coded as Developing, used a free problem posing framework to study PSTs' development of mathematical modeling problems for the primary classroom. This study and Chapman's share a focus on creating new tasks, which we include as part of the task design action of Developing, in a free problem posing context. Chapman (2007) also shares commonalities with other fields of research, such as Navarro and Céspedes (2022), which we coded as Evaluating and is focused on developing PSTs' "critical and constructive analysis of mathematics textbook lessons" (p. 166). Because these studies make clear the practical actions under study, we can apply our TDA framework to find connections and coherence across different fields.

6 Concluding remarks

The findings from this scoping review highlight the essential role of task design in mathematics education, particularly within the context of pre-service teacher (PST) education. By examining the actions of modifying, evaluating, developing, selecting, and sequencing (MEDSS), we gained a more comprehensive understanding of how PSTs engage with tasks to enhance their pedagogical skills, support student learning, and gain experience in local curriculum documents and resources across the range of theoretical and methodological frameworks relevant to task design.

The MEDSS-TDA framework provides a valuable structure for understanding and categorizing the diverse activities involved in task design. This framework allows for a systematic examination of how PSTs interact with tasks, whether through modification, evaluation, development, selection, or sequencing. By applying the MEDSS-TDA framework, researchers and educators can bring together disparate strands of task design literature, offering a cohesive lens through which to view and compare different studies. This unified approach not only clarifies the specific actions involved in task design but also highlights the interconnections between various research efforts, fostering a more integrated understanding of the field.

The insights gained from this review have several possible implications for PST education. First, emphasizing the explicit teaching and practice of task design actions might enhance PSTs' ability to create and adapt tasks that meet diverse student needs and curricular goals. For example, providing opportunities for PSTs to engage in modifying tasks helps them develop skills in adapting existing resources to better fit their instructional contexts. Similarly, encouraging PSTs to develop new tasks from scratch could foster creativity and deepen their understanding of mathematical concepts and pedagogy. Moreover, the ability to evaluate tasks critically is crucial for PSTs to ensure that the tasks they use or create are effective in promoting student learning. This involves not only assessing the cognitive demands of tasks but also considering their accessibility and relevance to students' experiences.

While task design is an essential component of all preservice education, we noted a lack of literature in this field. Inconsistent terminology across the literature and lack of clearly specified task design actions within the studies also made it challenging to compile the literature for this scoping review. This review highlights the need to explore the various dimensions of task design actions and their impact on PSTs' professional development and instructional practices. Additionally, further research is needed to investigate the sequencing of tasks, an area identified as underrepresented in the current literature. Understanding how PSTs learn to sequence tasks to build coherent and cumulative learning experiences for students is essential for advancing task design research.

The MEDSS-TDA framework offers a comprehensive and unifying approach to studying task design in mathematics education. By categorizing and analyzing task design actions, this framework helps bridge gaps between different research studies and provides a clearer picture of how PSTs engage with tasks. The findings from this scoping review underscore the importance of task design in PST education and highlight the need for ongoing research to deepen our understanding of these critical pedagogical practices and theoretical frameworks.

Author contributions

JM: Writing – original draft, Writing – review & editing. LM: Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This report draws on research supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada (Grant no. 430-2023-00460).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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