

Advances in Task Design in Mathematics Education

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Abstract

Tasks and task design are central to the teaching and learning of mathematics. Task design has received considerable attention in the mathematics education research community, including topic study groups, themes to guide the study of task design, and calls for needed research directions. Employing a “tensions of intentions” perspective on task design, this systematic literature review examines recent advances, presenting results of analysis of 101 refereed journal articles published since 2020. Using classical content analysis, characteristics of the corpus of articles are presented along eight categories: journal publications and years, geographical distribution, content domains, task intended audiences, sample size and methods, theoretical and conceptual perspectives, task sources and design process, and mention of the COVID-19 global pandemic. Using themeing analysis, three themes emerged: involving teachers as task (re)designers, designing for assessment and/or significance testing, and designing to foreground linguistic, critical, and cultural perspectives. Interpretation across themes resulted in a “socio-didactical triangular dipyramid” for task design, expanding Rezat and Straßer’s socio-didactical tetrahedron. Implications for future research on task design, as well as limitations of the current study, are discussed.

Keywords: task design, tasks, mathematics education, systematic literature review, tensions of intentions, themeing analysis

1. Introduction and Rationale

Mathematical tasks are central to mathematics teaching and learning. Hence, research on mathematical task design is vital. Task design involves overlapping and diverse groups, including designers who develop tasks, teachers who implement tasks, and students who undertake tasks (Johnson et al., 2017; Jones & Pepin, 2016; Watson & Ohtani, 2015). For example, designers also can be teachers implementing the tasks, teachers also can be researchers, and students can refer to a broad range of learners, spanning children through adults. Mathematics education researchers have demonstrated substantial interest in task design, evidenced by the prominence of task design research in the community.

At the International Commission on Mathematical Instruction (ICMI) study (Watson & Ohtani, 2015) on task design, five themes were offered: (1) frameworks and principles, (2) a relationship between tasks, teaching, and learning, (3) the role of the student, (4) text-based tasks, and (5) the role of tools. The role of the student spurred a research forum at a meeting of the International Group for the Psychology of Mathematics Education (Clarke et al., 2014) and a special issue of *ZDM: The International Journal on Mathematics Education* (Johnson et al., 2017). Despite this attention, in the thematic study group at the thirteenth Congress of European Research in Mathematics Education, the role of the student in task design was identified as an area still needing further study (Olsher et al., 2023). At the topic study group at the fourteenth International Congress on Mathematical Education, themes from the ICMI study continued to be discussed, along with a call for the investigation of political and ethical dimensions of task design research, as well as new methodological approaches (Ohtani et al., 2024).

Given the continuing attention to themes raised at the ICMI study, along with new calls emerging, a literature review on task design is warranted. With this literature review, we provide

an account of advances in task design since 2020, when the global pandemic disrupted society, with lingering ripple effects for groups involved in (and impacted by) task design. Our aim is twofold. First, we report on characteristics of studies examining task design, and second, we discuss themes emerging across the studies.

2. Background: Mathematical Tasks, Task Design, and Theoretical Underpinnings

2.1 Mathematical Tasks

Mathematical tasks are something more than written problems. They are “a form of social practice, undertaken by teacher and students as a collective” (Johnson et al., 2017, p. 814). This practice involves people who design, enact, and engage with tasks, along with related artifacts (e.g., written materials, digital tools). Borrowing from film studies, we use the term “intended audience” to mean the people for whom the tasks are designed (see also Remillard, 2011). Tasks can have a single intended audience (e.g., elementary students) or multiple intended audiences (e.g., preservice teachers and secondary students).

Tasks can take a variety of different forms. We use “digital” and “analog” to distinguish two broad categories of tasks, with analog meaning something neither digital nor computerized (<https://www.merriam-webster.com/dictionary/analog>). Tasks also can be both digital and analog (e.g., Soury-Lavergne, 2021). We use analog rather than other terms such as traditional, conventional, or paper/pencil, because digital tasks may be traditional or conventional, and paper/pencil does not encompass the entirety of non-digital tasks.

2.2 Mathematical Task Design

Mathematical task design is multidimensional, including that which is to be designed, the tools to be used for design, and the conditions under which design may occur (Jones & Pepin, 2016). The tasks to be designed can include a range of content areas, drawing on a single area, or

extending across multiple content domains. Like the tasks themselves, tools may be digital or analog. Because task design involves multiple constituent groups, conditions underlying the design relate to the needs and goals of the different groups, including students as well as teachers/designers (Johnson et al., 2017). Appealing to a need for authentic and practical task implementation, Jones and Pepin (2016) have implored researchers to include teachers as partners in task design, not just as passive recipients of tasks.

Because tasks constitute a social practice, task design involves navigating intentions of overlapping groups. This includes the intentions of designers who develop tasks, the intentions of teachers who implement tasks, and the perspective of students who experience tasks (Johnson et al., 2017). A priori and iterative approaches to task design can provide a window into temporal relationships between intentions of different groups. With an a priori approach, tasks are designed prior to implementation. Here, designers' and teachers' intentions operate in parallel, with designers developing tasks for subsequent implementation by teachers. With an iterative approach, tasks are designed (and re-designed) in response to implementation. Here, designers' and teachers' intentions intersect, with both groups informing task design (and re-design). The intentions of designers and teachers also can operate in parallel or intersect with students' intentions for a task. For example, teachers may implement tasks asynchronously, operating in parallel with students. Designers also may be teachers who implement tasks synchronously with students, allowing for real-time intersections with their students' intentions.

There are strong connections between task design and design research (Kieran et al., 2015; Ruthven et al., 2009). In a design experiment study, there are three iterative phases (or cycles): making preparations for the experiment, conducting the experiment in an educational setting, and carrying out retrospective analysis (Cobb & Gravemeijer, 2006). The first two

phases overlap with different purposes for task design, namely “design as intention” and “design as implementation” (Kieran et al., 2015; Ruthven et al., 2009). The former addresses task formulation and the latter addresses the integration of tasks into educational settings.

Importantly, these purposes are not mutually exclusive. Task design includes not only designers’ intentions, but also the intentions of teachers and students who implement and experience the tasks.

Since 2020, digital task design generated strong interest, with two systematic literature reviews on the topic. Cevikbas and Kaiser (2021) examined task design for dynamic and interactive mathematical learning environments, with studies drawing on a range of theoretical perspectives. One challenge identified was task design for assessment, with a recommendation for flexible approaches, namely the use of tasks combining paper/pencil and digital elements. Pederson et al. (2021) offered recommendations for digital task design to engender students’ mathematical representation competency. These included leveraging feedback potential with digital task design, for instance, to have students make predictions prior to interacting with linked digital tools. Findings from these review studies evidenced nuanced ways in which teaching and learning could be mediated by digital tasks.

2.3 Theorizing Mathematical Task Design

Task design research in mathematics education draws on a wide range of theories, which is compatible with broader conversations around theorizing in mathematics education (Bikner-Ahsbabs et al., 2014). The networking of theories (Bikner-Ahsbabs & Prediger, 2010), a research approach in which researchers interconnect different theoretical perspectives, has been fruitful for advancing task design research (Huang et al., 2023). Theoretical frameworks for task design can range in scope from grand, to intermediate level, to domain specific (Kieran, 2019;

Watson, 2016). While grand theories can provide overarching guidance, by drawing on intermediate frames, researchers can develop theoretically grounded principles for task design that can extend domain-specific theorizing around particular forms of mathematical content or reasoning. Intermediate and domain-specific theorizing show strong promise for advancing task design research (Confrey et al., 2017).

To frame this literature review, we employ a “tensions of intentions” perspective on task design research (Johnson et al., 2017). This perspective draws on Rezat and Sträßer’s (2012) socio-didactical tetrahedron, grounded in socio-cultural and activity theory (Engeström, 1987). The tetrahedron adds the dimension of tasks to the didactical triangle of teachers, students, and mathematics, allowing for the examination of how tasks may mediate the teaching and learning of mathematics. Each edge of the tetrahedron represents a paired relationship (i.e., teacher-student, teacher-task, teacher-mathematics, student-task, student-mathematics, task-mathematics). Tensions can arise when relationships between different pairs are mapped onto each other (Johnson et al., 2017). For example, a teacher’s intention for the mathematics that students are to learn (teacher-mathematics) may not map well onto students’ experience of a task implemented in the classroom (student-task). Hence, students’ intentions are integral to a task’s purpose (Ainley et al., 2006), with implications for task designers to position students’ intentions at least to a similar degree as teachers’ intentions.

3. Methods

Our purpose is to understand recent advances in task design in mathematics education, through a systematic literature search. We ask two research questions: (1) What are characteristics of articles focused on task design in mathematics education, published since 2020 (i.e., journal publications and years, geographical distribution, content domains, task intended

audiences, sample size and methods, theoretical and conceptual perspectives, task sources and design approaches, and mention of the COVID-19 global pandemic)? (2) What themes emerge from articles focused on task design in mathematics education, published since 2020? Next, we describe our process.

3.1 Systematic Literature Search

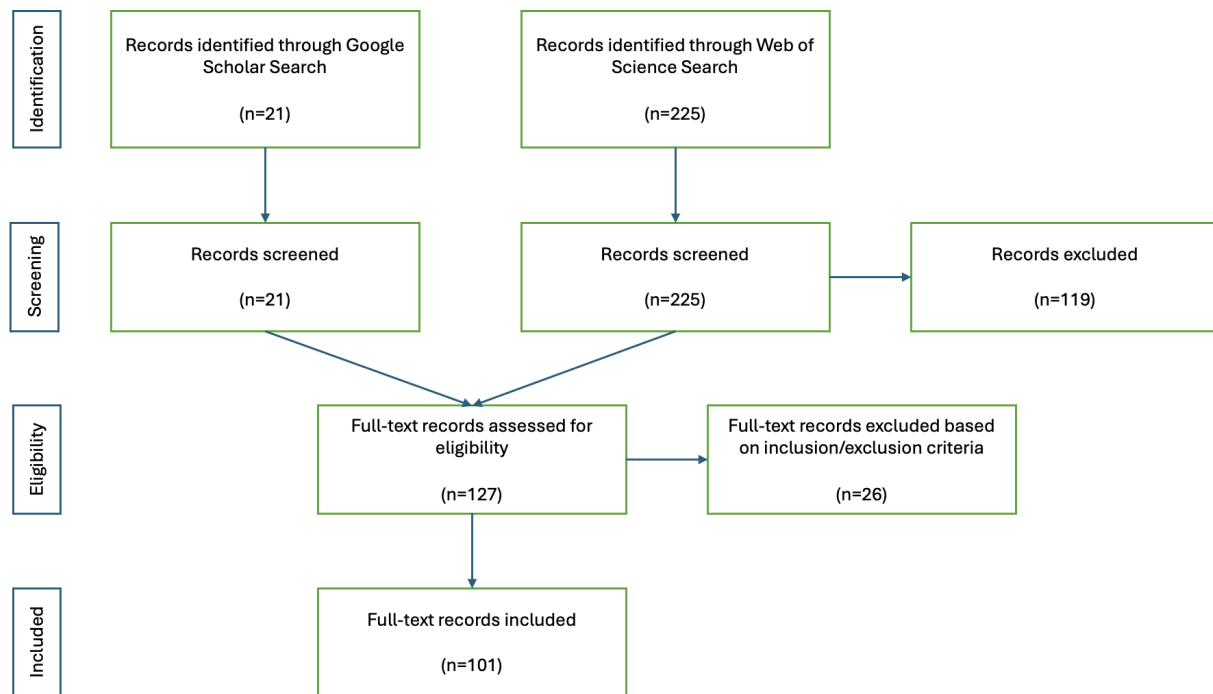
We conducted a literature search, using two well-known search engines, the Web of Science (WoS) and Google Scholar, for publications within the date range from January 1, 2020 through March 18, 2024. We used the WoS as our main search engine, supplementing with Google Scholar. We added Google Scholar to include two well-known mathematics education journals, *For the Learning of Mathematics (FLM)* and *Digital Experiences in Mathematics Education (DEME)*, which were not listed in the WoS. We made this choice based on the reputation and scope of FLM and DEME. A study on journal quality in mathematics education (Williams & Leatham, 2017) pointed to the high quality of FLM. While DEME was too new to be included in the journal quality study, we expected articles on task design to be included due to DEME's focus on contributions of digital experiences to teaching and learning mathematics.

For the WoS, we applied the following search strings: "Title=(task*) AND Abstract=(task* design* math*) AND Task Design (Should - Search within topic) AND Article or Review Article (Document Types) AND Education Educational Research or Mathematics or Psychology Educational (Web of Science Categories) AND English (Languages)." This electronic search yielded 225 articles. To screen the collection of articles, we used two criteria: (a) language: the entire article is written in English, because the search yielded articles with only abstracts written in English; (b) domain: the article addresses the discipline of mathematics education. In the screening process, we read the titles, abstracts, and keywords, and first lines of

each article. This resulted in 106 articles.

For Google Scholar, we applied two advanced searches, limited to publications since 2020. The first had the criteria: “Find articles with the exact phrase (task design) AND Return articles published in (Digital Experiences in Mathematics Education).” This yielded 16 articles. The second had the criteria: “Find articles with the exact phrase (task design) AND Return articles published in (For the Learning of Mathematics).” This yielded 5 articles. Because the Google Scholar search was limited to mathematics education journals written in English, it was not necessary to apply the two additional screening criteria used for the WoS search. Hence, this resulted in 21 articles.

Together, the searches yielded 127 articles. To organize, manage, and cite the collection of articles, Johnson used Paperpile Reference Manager. To curate the articles for analysis, Johnson used Google Sheets, organizing the articles by year, citation, journal, type of article, and type of task. Then, we examined the full texts of the 127 articles, to determine eligibility. These were the inclusion/exclusion criteria used: (a) include: articles that make explicit the designers’ purposes for the tasks to promote the teaching and/or learning of mathematics; (b) exclude: articles that do not make explicit the designers’ purposes for tasks (e.g., studies that compare students’ performance on existing tasks; studies that provide a new tool or framework to analyze existing tasks); (c) exclude: literature reviews/survey papers. The second round of screening resulted in a corpus of 101 articles to include in the review. Figure 1 shows the article selection process.

Figure 1. Flow diagram of article selection process

3.2 Data Analysis

We use two types of analysis. For the first research question, we perform classical content analysis (Berelson, 1952; Krippendorff, 1980) along eight categories: publication years and journals, geographical distribution, content domain, intended audience for tasks, sample size and methods, theoretical and/or conceptual perspectives, task sources and design approaches, and mention of the COVID-19 global pandemic. We also include data visualizations created with Microsoft Excel. For the second research question, we employ the analytic process of themeing the data (Saldaña, 2013). In this process, a theme is “an *extended phrase* or *sentence* that identifies what a unit of data is *about* and/or what it *means*” (p. 175). Themeing the data is particularly useful for meta-studies that look across existing studies, in part because the process allows themes to emerge via analysis.

Prior to themeing the data, in addition to the eight categories above, Johnson summarized each article along six additional categories: description of task(s), designers' intentions for tasks, designers' principles/guidelines for task design, research question(s)/aim, findings/recommendations, and discussion/implications. Then, Johnson vetted those summaries with Ohtani. Summaries served as sources of data for themeing. To theme the data, we read and reflected on the summaries, guided by the tensions of intentions perspective. Within each theme, we examined potential mappings of different paired relationships along edges of Rezat and Sträßer's (2012) socio-didactical tetrahedron (e.g., designers/teachers' intended mathematics and the mathematics students actually use). Three themes emerged: involving teachers as task (re)designers, designing for assessment and/or significance testing, and designing to foreground linguistic, critical, and cultural perspectives. After themeing, we made interpretations across the themes, to provide further advancement.

4. Characteristics of the Articles

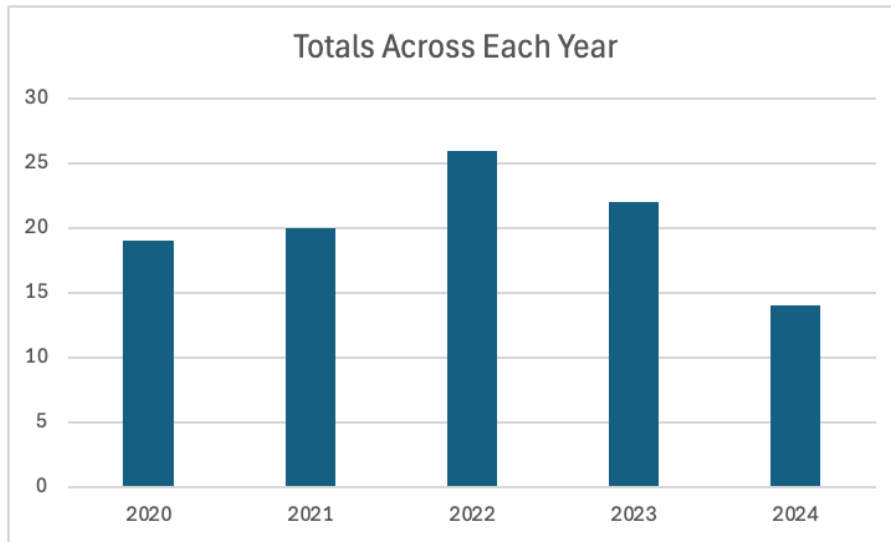
Of the 101 articles, 91 are empirical studies and 10 are design studies. By design study, we mean a conceptual or theoretical article discussing issues related to task design. The articles address analog tasks (n=47), digital tasks (n=40), and tasks that are both digital and analog (n=14). Next we discuss characteristics across eight categories.

4.1 Journal Publications and Years

The articles were published in 28 different journals, 16 with a mathematics education audience, and 12 with a general education audience. Eighty-six articles (85%) were published in mathematics education journals, and 15 articles (15%) were published in journals with a general education audience. Figure 2 shows the total number of articles published across the four years: 2020 (n=19, 19%), 2021 (n=20, 20%), 2022 (n=26, 25%), 2023 (n=22, 22%), 2024 (n=14, 14%).

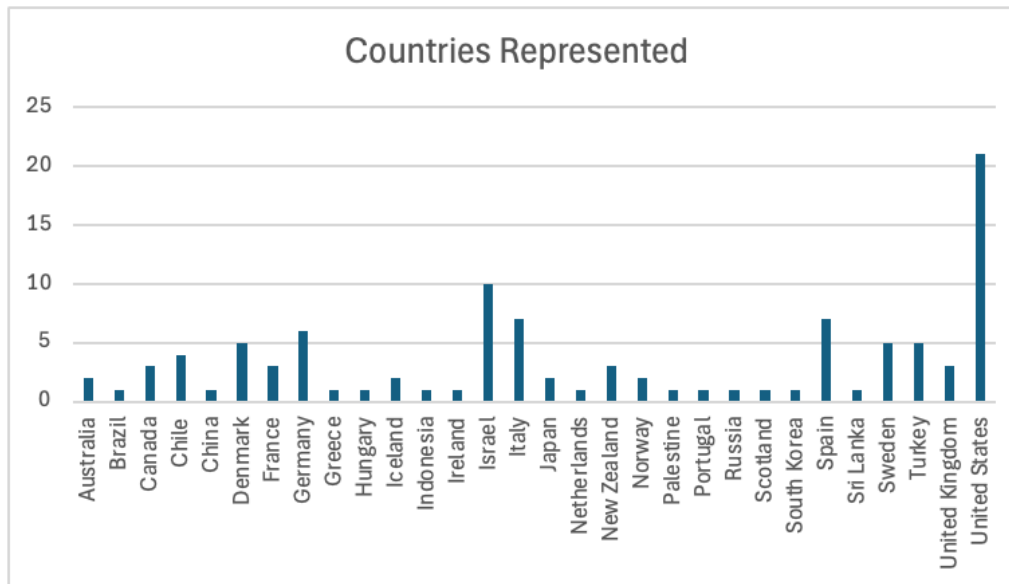
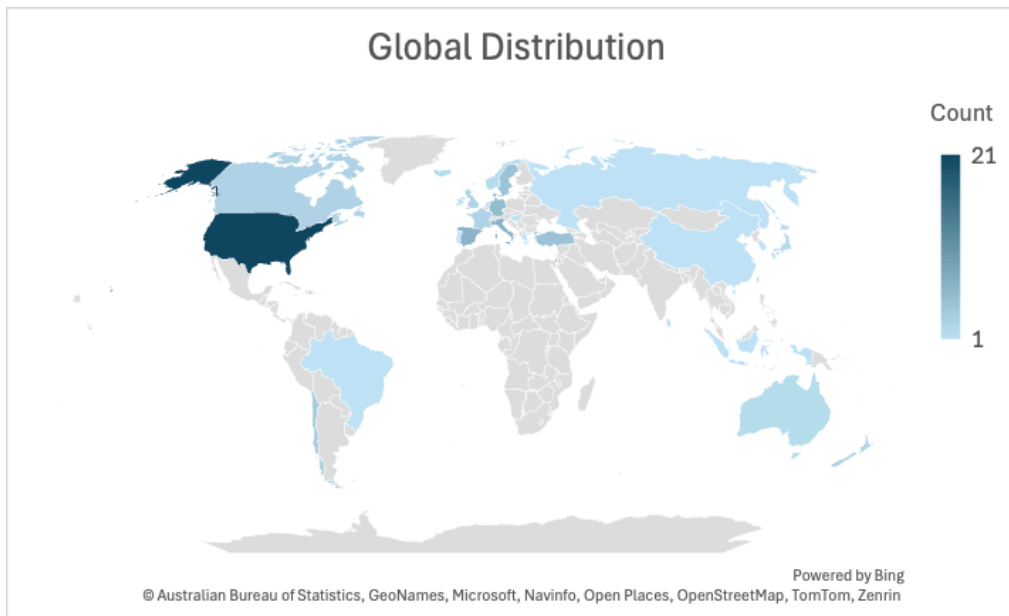
While just under a quarter of 2024 was included, the number of articles suggests promise for growth in task design research.

Figure 2. Totals across each year



4.2 Geographical Distribution

Figure 3 shows the countries represented ($n=30$) and the number of studies taking place in each country. Because two studies took place in two different countries (Gustafsson, 2024; Stylianides & Stylianides, 2022), the study count is 103. Figure 4 shows the global distribution of the studies. While there is a wide range of countries, the southern hemisphere is underrepresented, comprising only 11% of the studies.

Figure 3. Countries where the studies took place**Figure 4. Global distribution of studies**

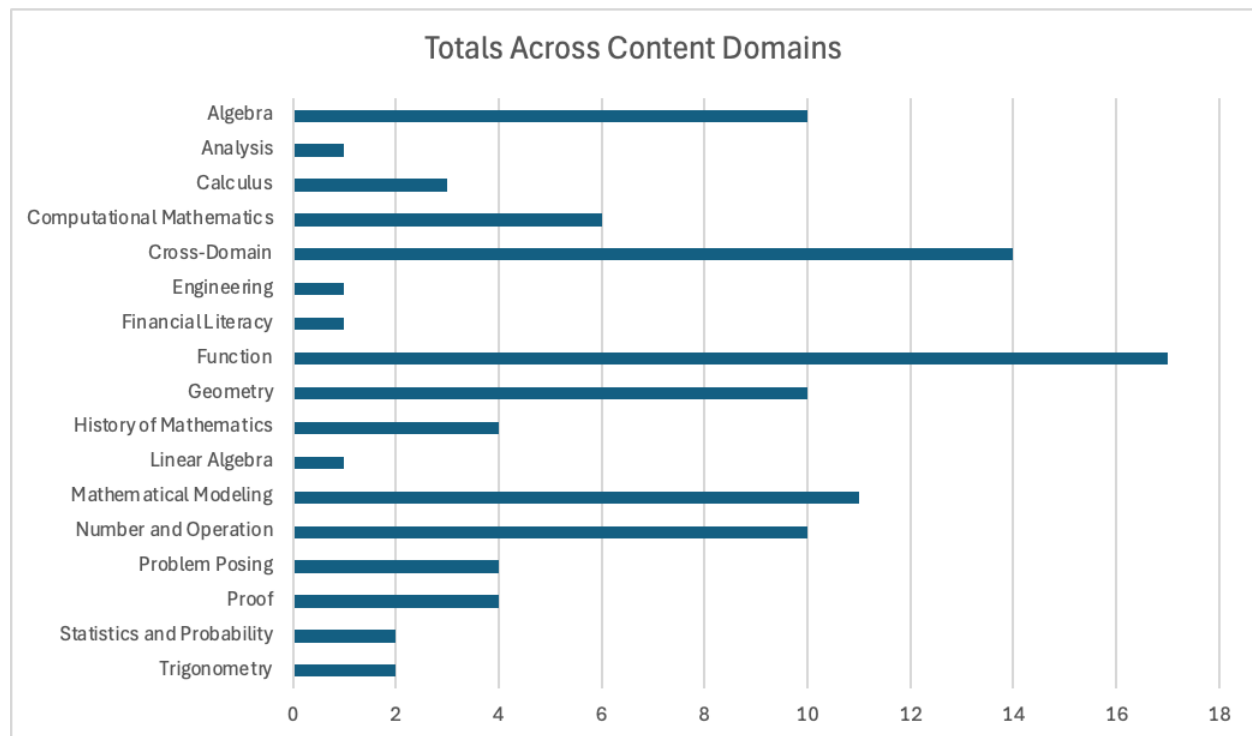
4.3 Content Domains

The tasks reported in the articles span 17 content domains: algebra ($n=10$, 10%), analysis ($n=1$, 1%), calculus ($n=3$, 3%), computational mathematics ($n=6$, 6%), cross-domain ($n=14$, 13%), engineering ($n=1$, 1%), financial literacy ($n=1$, 1%), function ($n=17$, 16%), geometry

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($n=10$, 10%), history of mathematics ($n=4$, 4%), linear algebra ($n=1$, 1%), mathematical modeling ($n=11$, 11%), number and operation ($n=10$, 10%), problem posing ($n=4$, 4%), proof, ($n=4$, 4%), statistics and probability ($n=2$, 2%), and trigonometry ($n=2$, 2%). Figure 5 displays the totals across the content domains. By cross-domain, we mean tasks designed to extend across a range of content domains. For example, drawing on Laurinda Brown's use of "relentless consistency," Sullivan et al. (2020) describe an approach to the design of sequences of challenging tasks that teachers could use and/or adapt to foster students' agency in making mathematical connections. The breadth of the content domains, from designing tasks in a multi-touch environment to support preschool students' development of early number (Baccaglini-Frank et al., 2020) to designing game-based tasks to foster postsecondary students' understanding of span in linear algebra (Bernier & Zandieh, 2024), speaks to the pervasiveness of research on task design in mathematics education.

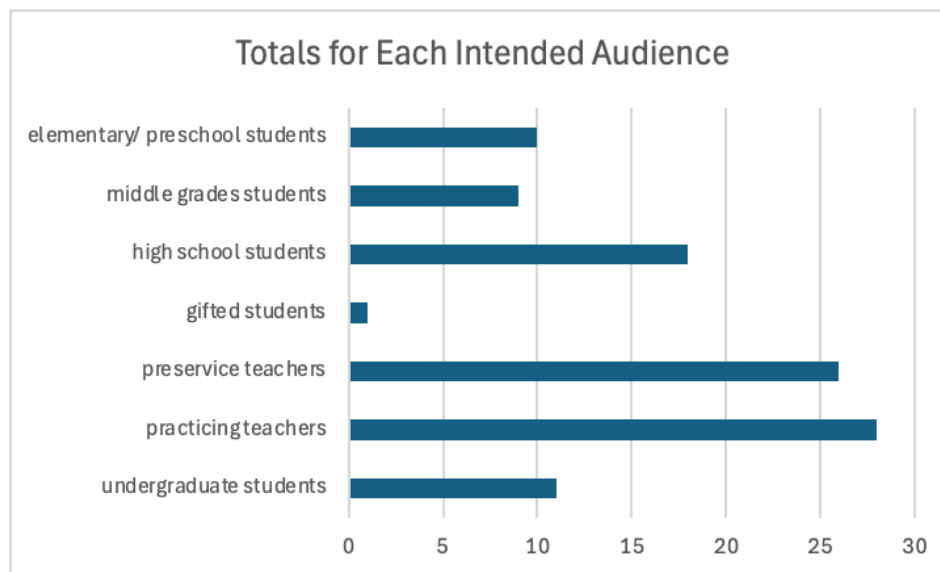
Figure 5. Totals across content domains



4.4 Intended Audiences for Tasks

The tasks discussed in the articles encompass seven intended audiences: elementary/preschool students ($n=10$, 10%), middle grades students ($n=9$, 9%), high school students ($n=18$, 17%), gifted students ($n=1$, 1%), practicing teachers ($n=28$, 27%), preservice teachers ($n=26$, 25%), and undergraduate students not identified as preservice teachers ($n=11$, 11%). Figure 6 shows the totals for each intended audience. For the studies focused on practicing teachers, twenty-seven included tasks designed for elementary and/or secondary teachers; one included tasks designed for undergraduate instructors (El Turkey et al., 2024). The total is 103, because two studies included tasks designed with multiple audiences in mind, namely preservice teachers and secondary students (Liang, 2023; Stylianides & Stylianides, 2022).

Figure 6. Totals for each intended audience

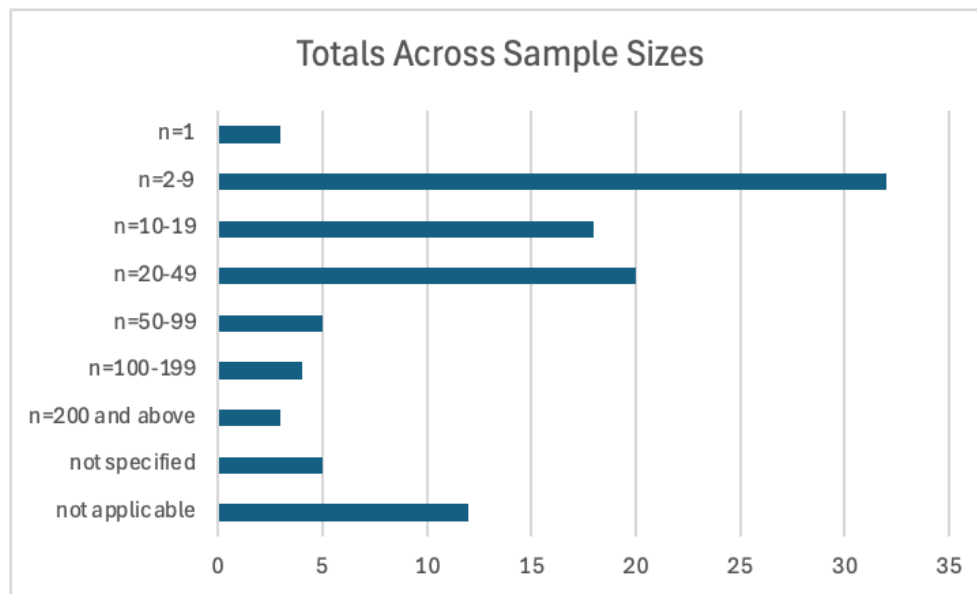


4.5 Sample Size and Methods

When we report sample size, we use the number of participants as the unit of analysis. The studies have a wide range of sample sizes: exactly 1 ($n=3$, 3%), between 2 and 9 ($n=32$, 31%), between 10 and 19 ($n=18$, 17.5%), between 20 and 49 ($n=20$, 19.5%), between 50 and 99

($n=5$, 5%), between 100 and 199 ($n=4$, 4%), 200 and above ($n=3$, 3%). Five studies (5%) do not specify the number of participants. For 12 studies, the number of participants is not applicable. This includes the 10 design studies, along with two studies employing the Anthropological Theory of the Didactic (Hochmuth, 2022; Schmidt & Winsløw, 2021). For Hochmuth (2022), the unit of analysis is the tasks themselves, and for Schmidt and Winsløw (2021), the unit of analysis is a university mathematics course, for which particular tasks were designed. Figure 7 shows the totals across sample sizes.

Figure 7. Totals across sample sizes



Of the 91 empirical studies, 81 used qualitative methods (89%), two used quantitative methods (2%), and eight used mixed methods (9%). For the qualitative studies, the most common methodologies were case study ($n=14$) and design-based research ($n=23$). The case studies included those three studies with sample size $n=1$, seven multiple case studies, and four studies in which a single case represented a group of teachers or students. The design-based research studies encompassed a range of sample sizes and over half of the content domains. Four

studies reported an experimental design, with two using qualitative methods and two using mixed methods.

4.6 Theoretical and Conceptual Perspectives

In all articles, there was explicit mention of theoretical and/or conceptual perspectives underlying the task design. Eighty-one different theoretical and/or conceptual perspectives were used to ground the studies. This range spoke to the diversity of theories and constructs being used in mathematics education research. Furthermore, in 26 articles, authors employed multiple perspectives to ground their studies, demonstrating the influence of the networking of theories approach on task design research.

Seven studies put forward principles for task design. These included design principles for digital classroom response tasks (Gustafsson & Ryve, 2022), inquiry calculus tasks (El Turkey et al., 2023), creativity-fostering tasks (El Turkey et al., 2024), mathematical tasks incorporating authentic problems of engineering (Schmidt & Winsløw, 2021), tasks addressing applications of undergraduate mathematics for teaching (Álvarez et al., 2020), tasks fostering the use of code-driven tools (Fergusson & Pfannkuch, 2022), and digital graphing tasks (Johnson, 2022). The development of new design principles demonstrated further advancement in intermediate level theorizing for task design in mathematics education.

Six studies put forward new (n=5) or adapted (n=1) frameworks/models for task design. These included a design and implementation framework for mathematical modeling tasks (Geiger et al., 2022), a framework to assess the richness of teacher-designed tasks (Ratnayake et al., 2020), a framework explaining a four-part structure for Fermi problems (Ärlebäck & Albarracín, 2024), and a Function-Operation-Matrix framework for digital task design to promote functional thinking (Günster & Weigand, 2020). Agterberg et al. (2022) presented a

model linking Smith and Stein's (1998) four levels of cognitively demanding tasks to four formats for history of mathematics tasks. Bernier and Zandieh (2024) adapted the strategy framework from Mauntel et. al (2021) for use with game-based linear algebra tasks. As predicted by Confrey et al. (2017), domain-specific theorizing in task design did continue, via developing new frameworks or adapting existing frameworks for particular purposes.

4.7 Task Sources and Design Approaches

Across the articles, 76 present new tasks, 23 present adapted tasks, and two present a combination of new and adapted tasks. Eighty studies use an a priori approach to task design, and 21 studies use an iterative approach. Of those 21 studies, eight (38%) use design-based research methodology, indicating that an iterative approach can extend to other methodologies as well. Despite the large corpus of extant mathematical tasks, the design of new tasks remains a fruitful area for research, with three-quarters of the studies reporting on the design of new tasks.

4.8 Mention of COVID-19 Global Pandemic

Because we reviewed articles published since 2020, we anticipated potential impact from the COVID-19 global pandemic. In nine articles, there was explicit mention of the global pandemic. In four studies, COVID-19 impacted aspects of the design, resulting in a delay in implementation cycles (Chorlay, 2022), an inability to conduct face-to-face observations (Pocalana & Robutti, 2024; Sand et al., 2022), and a pivot to an online instrument (Rach & Schukajlow, 2023). One study investigated teachers' task design for distance learning, in response to pandemic restrictions on face-to-face learning (Daher et al., 2023).

5. Three Themes for Task Design in Mathematics Education

From a “tensions of intentions” perspective, themes served to illuminate relationships between overlapping groups, revealing potential tensions that might arise among the

interconnected relationships. The first theme, teachers as task (re)designers, included 36 articles. The second theme, task design for assessment and/or significance testing, included 12 articles. The third theme, task design to foreground linguistic, cultural, and/or critical perspectives, included 10 articles. Not surprisingly, some articles addressed more than one theme; five were common to the first and second themes, five to the first and third themes, and one to the second and third themes.

5.1 Teachers as Task (Re)designers

When teachers served as task (re)designers, there was overlap between the purposes of “design as intention” and “design as implementation.” In 26 studies, practicing and/or preservice teachers designed (or redesigned) tasks from a student perspective. This included how students might experience the task and/or the mathematics students might bring to the task. Wickstrom and Arnold (2023) engaged preservice secondary teachers in designing and implementing modeling tasks. They found that teachers’ emerging task competencies were linked to the task situations; when the task situation was more familiar, they were better able to anticipate potential student responses. Martin’s (2021) study illuminated a preservice elementary teacher’s capacity to design tasks to connect operations with decimal numbers to her students’ lived experiences with water travel by ferry. The teacher designed the ferry task because she thought that a situation that was meaningful for her students could help them to make sense of the operations, beyond just following rules. Two studies drew on practicing teachers’ task design to allow students to engage in mathematizing to explore and critique social and cultural issues, overlapping with the third theme. During a summer professional development institute, Turner et al. (2024) engaged practicing elementary teachers in designing mathematical modeling tasks, intended to resemble to students’ lived experiences, raise questions of personal and community

value, and allow solutions to impact students' communities. They contended that teachers' design could lead to more authentic modeling tasks in implementation, when supports were available to the teachers. Estrella et al. (2020) engaged practicing elementary teachers in designing a statistics task in which students were to organize and collect data about their snack consumption, and weigh that against the risk of contracting diseases. They found that scaffolding fostered teachers' task implementation to maintain higher levels of cognitive demand. These studies illuminated interconnections between intention and implementation in design, including the value-laden decisions underlying task design centering the student's perspective.

One way to mitigate tensions between designers' and teachers' intentions for tasks was to collaborate in task (re)design, accounting for half of the studies (n=18) in this theme. The overwhelming majority of these studies involved collaboration between designers/researchers and practicing teachers. Collaboration took a variety of forms, and the studies used a range of design approaches. Estrella et al. (2020) used a lesson study approach to task (re)design. They contended that the collaboration between researchers and teachers encouraged teachers to make strong arguments about how they might improve task implementation to promote students' meaningful participation. Gustafsson (2024) used a draft and revision model for collaborative task (re)design. Drawing on Gustafsson and Ryve's (2022) framework, Gustafsson (2024) first developed drafts of multiple choice tasks, to use in combination with a digital classroom response system, then shared those tasks with practicing teachers, who suggested revisions and clarifications, from which the final tasks were developed. Geiger et al. (2022) leveraged individual teacher-researcher meetings for collaboration. Their study examined how practicing secondary teachers developed competency using modeling tasks and instruction, and they found it productive to consider design and implementation as two sides of the same coin. These studies

highlighted the reflexive relationship between task design and implementation that can arise with collaborative task design; a need for implementation can drive task design and inform cycles of redesign.

Task (re)design served as a topic of preservice teacher education, encompassing 14 studies. In this educational setting, tensions between groups could occur at multiple levels, between researchers' and preservice intentions for tasks and mathematics to be learned, as well as the perspectives of students for whom the tasks would be designed. Martínez-Jiménez et al. (2022) surfaced tensions about the mathematics to be learned. In their study, preservice elementary teachers designed "math trail" tasks in which their students could explore geometrical ideas via a structured walk through their local community. Teachers' task design provided evidence of their conceptions of what constituted geometry, emphasizing the calculation of perimeter, area, and volume, which was different from what the researchers had intended. Guerrero-Ortiz and Camacho-Machín (2022) surfaced tensions relating to preservice teachers' experience with school mathematics as content to be covered. In this study, preservice teachers were less likely to develop modeling tasks involving exploration, which aligned with the researchers' intentions. de Araujo et al. (2021) surfaced tensions between preservice teachers' expectations for students and nature of adaptations that they made to tasks. Across the studies, findings suggested that task (re)design is a challenging endeavor for preservice teachers and included calls for explicit support in teacher education programs (e.g., Dempsey & O'Shea, 2020).

5.2 Task Design for Assessment and/or Significance Testing

With task design for assessment, tensions might arise between designers' intentions for the mathematics that students are to demonstrate having learned and students' experiences with

the tasks. Five studies examined how artifacts from preservice or practicing teachers' task design could be used for assessment, constituting the overlap between the first and second themes. In one study, task design itself was the object of assessment (Dempsey & O'Shea, 2020). In four studies (Gustafsson, 2024; Gustafsson & Ryve, 2022; Olsher & Lavie, 2023; Pincheira & Alsina, 2022), task design served as a vehicle to assess teachers' and/or students' mathematical competencies.

Preservice teachers' task design was a source of assessment in three studies. In a learning module for preservice secondary teachers (n=19), Dempsey and O'Shea (2020) included an assessment item in which teachers were to design (or significantly adapt) a task or set of tasks for a content area of their choice. While all teachers demonstrated competency with task design/adaptation, the findings revealed a need for more experiences with task design in their teacher education program. Using digital geometry tasks designed by preservice elementary teachers (n=66), Olsher and Lavie (2023) examined levels of generalization that were present in anticipated student responses that the teachers developed to accompany the tasks. While a range of levels of generalization were present in the hypothetical responses, the preservice elementary teachers had few experiences engaging in open-ended tasks like the ones they were to design. Pincheira and Alsina (2022) drew on mathematical pattern tasks designed by preservice early childhood/elementary teachers (n=40), to assess their mathematical knowledge for teaching (MKT). Findings revealed differences in teachers' competencies within subdomains of MKT, with implications pointing to teachers' experiences with task design. Across these studies, artifacts of preservice teachers' task design were viable sources of data for assessing mathematical and pedagogical competencies. Yet, findings surfaced tensions between preservice teachers' need for more task design experiences in teacher education programs and designers'

intentions for teachers' task design, leading to changes in one program based on the results (Dempsey & O'Shea, 2020).

Four studies engaged in significance testing; one used quantitative methods (Rach & Schukajlow, 2023) and three used mixed methods (Albarracín et al., 2022; Baumanns & Rott, 2024; Putra et al., 2022). Rach and Schukajlow (2023) designed an assessment to examine whether task context (numerical operations connected to teachers' professional work vs. numerical operations without such connections) would affect preservice elementary and secondary teachers' (n=133) views of task utility, cost, and effort. Tasks came in pairs, based on context; teachers randomly received one of the paired tasks. Findings showed that tasks with connection to teachers' professional work significantly affected teachers' task utility value (small to medium effect size) and costs (small effect size), but there was no effect on teachers' effort. Using an experimental design, Albarracín et al. (2022) examined how "upscaling" could support high school students' (n=154) development of more complex mathematical models. With "upscaling," a set of tasks addressed the same general problem of making an estimate of how many people could fit in a particular location, with contextual details moving from accessible and known (e.g., a phenomenon in their location) to inaccessible and unknown (e.g., the same phenomenon in an unfamiliar location). While the experimental group showed a significant difference in performance, it did not also connect to more complex mathematical models. Interestingly, the novelty of the task for students in the control group seemed to lead them to try more strategies. Baumanns and Rott (2024) also found mixed results in their study of the effects of problem posing tasks on preservice elementary teachers' (n=187) performance and self-efficacy. They found neither the topic of the task (pentagons vs. tiles) nor the situation of the task (structured/unstructured) to influence performance. In fact, there was a weak negative

correlation between performance and self-efficacy: the higher the performance, the lower the self-efficacy. Results of these studies pointed to tensions arising between designers' intentions for the mathematics to be assessed and students' (preservice teachers and high school students) experiences with the assessment tasks.

5.3 Task Design to Foreground Linguistic, Cultural, and/or Critical Perspectives

One way to expand on the role of the student in task design (Clarke et al., 2014; Johnson et al., 2017) is by foregrounding linguistic, cultural, and critical perspectives. This focus of task design accounts for students as members of communities (typically nondominant) that extend beyond the classroom. Three studies foregrounded underrepresented cultural perspectives in their task design. Borden et al. (2021) designed tasks for elementary students to “verbify” multiplication, and thereby align with the Mi’kmaq worldview, in which movement and flux are crucial to learning. Overlapping with the second theme, Putra et al. (2022) designed an assessment that foregrounded Riau-Malay culture, to assess elementary students’ computational thinking. The assessment was shown to be valid and reliable, and Putra et al. (2022) recommended that further task design be done to foreground different cultural contexts. Hunter et al. (2022) designed a culturally located task, using a familiar Pācific context, to support function learning for middle grades students. Across these studies, the purpose of the tasks was interconnected not only to students’ experiences of the task in the classroom (Ainley et al., 2006), but also to students’ cultural competencies in their communities.

Four studies foregrounded linguistic considerations with task design. Two examined task design for students learning the dominant language as an additional language. Overlapping with the first theme, de Araujo et al. (2021) examined how preservice elementary teachers adapted tasks for students learning English as an additional language. They found that teachers’

expectations for their students impacted their task adaptations; when teachers had lower expectations, they tended to adapt to remove language barriers, rather than supporting students to expand their linguistic resources. In a small design experiment study, Zentgraf and Prediger (2024) adapted the well-known bottle problem task for high school students learning German as an additional language. Implications from their study included the redesign of curricular materials, to support teachers in the use of relevant scaffolds to support students' navigation of multiple demands. Overlapping with the first theme, two studies considered the role of informal and formal language in mathematical tasks. With a classroom teacher, Gíslason (2021) collaboratively designed digital tasks to allow students to communicate informally about the points on the screen, prior to using formal language. Carmona-Medeiro et al. (2024) examined how a teacher went back and forth between formal and informal language, in response to students. Together, these studies demonstrated how researchers could leverage language in mathematical task design to mitigate tensions between students' experiences of the task and teachers' intentions for mathematics to be learned.

6. Discussion and Conclusion

6.1 Limitations and Summary of Research Questions

We conducted a systematic literature review on task design in mathematics education research, since 2020. The corpus of 101 articles underscored the relevance and pervasiveness of task design in mathematics education research. Limitations arose in two areas. First, we limited our search to peer-reviewed journal articles published in English. Second, we included only those articles that made explicit designers' purposes for tasks. This choice meant that articles reporting on the analysis of existing tasks (e.g., textbook analyses) only were included if designers' purposes for tasks were explicitly discussed. A future literature review could focus solely on

mathematics task design for textbooks. With the “tensions of intentions” perspective, we focused our theming analysis on relationships between overlapping groups involved in task design.

For the first research question, the articles were published in a variety of journals, with a wide geographic distribution, including a broad range of content domains, intended audiences for tasks, sample sizes, and theoretical perspectives employed. While the COVID-19 global pandemic was mentioned in nine articles, we had expected even more to address it. This could be due to the length of time to publish refereed journal articles, as a number of studies were conducted before the pandemic. The new and/or adapted design principles and frameworks evidenced the utility of intermediate level and domain-specific theorizing (Kieran, 2019; Watson, 2016) for advancing task design research. The underrepresentation of the southern hemisphere suggested a need for more research from this broad region of the world.

For the second research question, we reported on three themes. The first theme, teachers as task (re)designers, evidenced the impact of Jones and Pepin’s (2016) call to include teachers as partners in task design. Given the sheer number of articles in this theme, it might warrant a literature review focused just on this area of task design. For instance, time frames before and after Jones and Pepin’s (2016) call could be selected for comparison. The second theme, task design for assessment and/or significance testing, pointed to tension between designers’ intentions for the assessment tasks and students’ experiences with those tasks. This added to the tension that Cevikbas and Kaiser (2021) found in their review on digital task design, namely a digital task’s capability to capture a student’s intended response. Future studies could draw out further tensions in task design for assessment, including tensions related to the object of task design (e.g., assessing teachers’ mathematical task design capabilities or students’ mathematical competencies). The third theme, task design to foreground linguistic, cultural, and/or critical

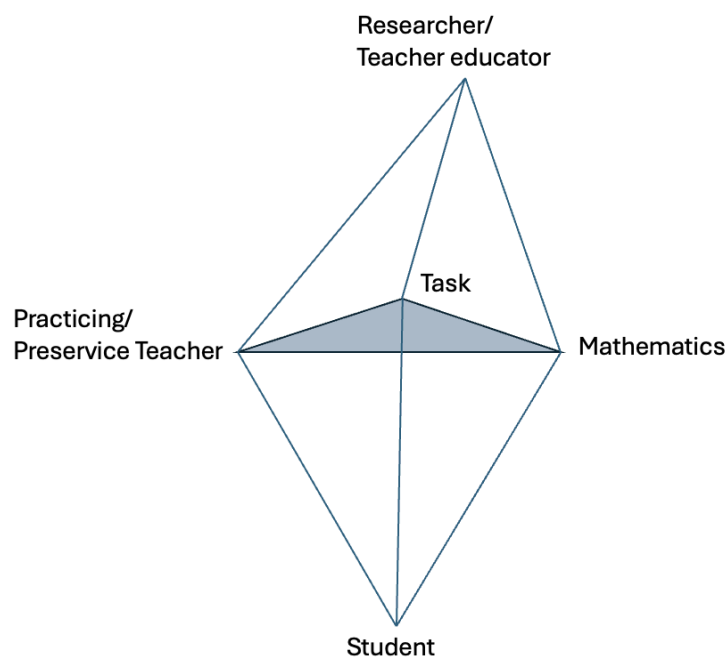
perspectives offered new directions in mathematical task design, connected to the call from Ohtani et al. (2024). Notably, in the ten studies addressing this theme, the southern hemisphere had better representation (30%). In future studies, researchers employing linguistic, cultural, and/or critical perspectives could work to expand what constitutes the role of the student in task design (Clarke et al., 2014; Johnson et al., 2017), to include students' communities extending beyond the classroom.

6.2 A Look Across Themes: The Socio-Didactical Triangular Dipyramid

A look across the themes revealed the potentiality for a “tension of intentions” among researchers/teacher educators, preservice/practicing teachers, and students. To account for the intentions of these three constituent groups, we propose expanding Rezat and Sträßer's (2012) socio-didactical tetrahedron into a socio-didactical triangular dipyramid (Figure 8). A triangular dipyramid is created by joining two tetrahedra along one face. The socio-didactical triangular dipyramid has five vertices (researchers/ teacher educators, preservice/ practicing teachers, students, tasks, mathematics) and nine edges, representing nine paired relationships. The teacher-task-mathematics face (internal to the triangular dipyramid) joins the two tetrahedra; this face represents the “teacher's task-mediated activity of doing and teaching mathematics” (Johnson et al., 2017, p. 815). By positioning teachers on a vertex shared by both tetrahedra, we represent the dual role that teachers can play when they are engaging in task (re)design. Teachers can be students, with respect to their relationship to researchers/ teacher educators. Concurrently, teachers also have a relationship to their students (i.e., students they teach or students they are preparing to teach). Furthermore, the triangular dipyramid allows for the examination of the intentions of task designers who are someone other than teachers. For example, textbook authors who design tasks to be used by teachers can be positioned at the researcher/ teacher educator

vertex. As a whole, the socio-didactical triangular dipyramid represents a dynamic system, linking teachers' roles as doers of mathematics to their roles of teachers of mathematics. While our analysis drew out tensions when paired relationships are mapped onto each other, future studies can use different units of analysis, such as relationships between the two tetrahedra (see also Prediger et al., 2019).

Figure 8. Socio-didactical triangular dipyramid, adapted from Rezat and Straßer's (2012) socio-didactical tetrahedron



6.3 Concluding Remarks

Although our review did not focus solely on digital task design, we saw an intriguing design principle emerge in five articles, namely, to design digital tasks to center gesture and movement in the learning of mathematics. This occurred on a whole-body scale (Rosenbaum et al., 2020), as well as with touch-screen interfaces for early number (Baccaglini-Frank et al., 2020; Güneş, 2021a, 2021b) and algebra (Janßen et al., 2020). These studies pointed to an

embodied approach to task design as a promising area for future research.

While most articles reported on the design of new tasks, adapting tasks for particular purposes represented a promising area of task design research. Three purposes included adapting tasks for different intended audiences, often preservice teachers (e.g., Ayalon & Wilkie, 2020), adapting analog tasks to become digital tasks (e.g., Janßen et al., 2020), and adapting tasks to foreground linguistic, critical, or cultural perspectives (e.g., Zentgraf & Prediger, 2024). The last purpose indicated one way to advance task design around the third theme of this literature review, an area that we view to be ripe for further research. In future task design research, it would be valuable to offer principles for adapting tasks to advance different purposes in mathematics education. This could include addressing ethical and socioecological dimensions of task design (see Barwell et al., 2022), which then could involve new methodical approaches.

To conclude, tasks and task design are at the heart of mathematics teaching and learning. In a report on future themes in mathematics education research, Bakker et al. (2021, p. 11) put forward this key challenge: “to assess what we value rather than valuing what we assess.” In our view, this challenge applies to task design as well as assessment. How do mathematical tasks and mathematical task design reflect what gets valued in mathematics education? And are those values ones we would endorse?

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