PRE-SERVICE TEACHERS' OPERATIONALIZATION OF COGNITIVE DEMAND ACROSS CONTEXT

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This research uses a framing perspective to examine how pre-service teachers (PSTs) conceptualize cognitive demand when selecting tasks. Our results show that PSTs' operationalizations of cognitive demand are context dependent. Within their methods class, PSTs largely think of cognitive demand in terms of how it promotes understanding of mathematics. When PSTs interact with students, they tend to operationalize cognitive demand as a way to support perceived student disposition and ability, or as a way to determine problem difficulty.

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Introduction

Selecting tasks that promote reasoning and problem solving is an important part of mathematics teaching (CAEP Standards, 2020). Research shows that selecting such tasks can be difficult for pre-service teachers (PSTs), but interventions in university methods classes can improve PSTs' ability to choose mathematically rich tasks (Crespo, 2003; Crespo & Sinclair, 2008; Leavy & Hourigan, 2019). Attending to the cognitive demand of tasks is one way to focus PSTs' attention on the mathematical features of tasks (Stein et al., 1996; Stein, Smith, Henningsen & Silver, 2000). *Cognitive demand* (CD) refers "to the kinds of thinking needed to solve tasks" (Stein et al., 2000, p. 3). Low-level tasks rely on applying memorized facts or procedures, requiring little understanding of the underlying mathematical concepts. In contrast, high-level tasks provide for multiple entry points and solution paths, requiring students to engage in meaningful inquiry and problem solving. While tasks of each level of CD support different learning goals, high-level CD tasks are linked to the greatest gains in student learning (Stein et al., 2000). Therefore, it is important that teachers be able to select high CD tasks for instruction.

As teacher educators, we are interested in how PSTs think about task selection in relation to CD as they move from a methods class to their internships. We ask, *how do PSTs operationalize cognitive demand in task selection across contexts?* For the purposes of this study, we consider two contexts: (1) reflecting on CD as students in a methods course that emphasizes rigorous mathematical tasks, and (2) applying CD when teaching middle grades students. Our study adds to the literature of task selection because it considers how PSTs reason about the CD of tasks, which impacts their task selection.

Theoretical Framework

We use the lens of *framing* to explain PSTs' changes in conception of CD across contexts. Framing has been used in science education research to describe how teachers and students understand particular educational contexts, and how that understanding impacts their ideas about knowledge, along with their actions and interactions with others (e.g., Hammer, Elby, Scherr, & Redish, 2005; Elby & Hammer, 2010; Richards et al., 2020). From this perspective, people learn by activating resources, which are "fine-grained knowledge elements" (Elby & Hammer, 2010, p. 410) based on factors such as lived experiences, social interactions, and beliefs. When resources are repeatedly activated together, they form "locally coherent sets" (Elby & Hammer, 2010, p. 413) called frames. In the classroom, these frames give a teacher or a student a sense of "what is going on here"

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(Hammer et al., 2005), which impacts how they interact with others and the content. A critical feature of this framework is that context determines the resources that people activate. Thus, framing allows for individuals to hold multiple beliefs or perceptions, while identifying which resources are foregrounded during a given activity.

Methods

This brief research report is a secondary analysis relying on a subset of data from a larger study that investigates middle grade mathematics and sciences PSTs' lesson planning behaviors throughout their early field experiences.

Middle grades mathematics methods course

The participants are 10 undergraduate PSTs in a middle grades mathematics and science dual certification program who completed a mediated field experience mathematics methods course, taught by the first author. The field experience component of the course took place at a local middle school, where PSTs selected and implemented tasks with small groups of students. The CD of mathematical tasks was explicitly and regularly addressed in the methods course.

Data sources

The data sources for this brief research report include PSTs' final course papers and the transcripts from two individual semi-structured interviews, conducted by the first author. The final course assignment (Fall 2018) asked PSTs to reflect on how the methods course supported their growth as a learner and doer of mathematics. The first interview was conducted the semester following the methods course (Spring 2019). PSTs were asked to reflect on their process for selecting tasks and preparing lesson plans for the after-school enrichment program. PSTs were probed for whether the CD of tasks played a role in their decision-making. The second interview was conducted a year after the methods course (Fall 2019). PSTs were asked about their teaching internship and to analyze tasks from the casebook authored by Stein, Smith, Henningsen, and Silver (2000).

Analysis

Our research builds on the work of Elby and colleagues (2020) who demonstrated how analysis of written reflections can provide teacher educators with insight on PSTs' framing of classroom activity in a more timely manner than the interaction-analysis techniques traditionally employed with a framing perspective. The authors describe this type of analysis as "framing lite." The data sources were initially coded by the first author for references to CD. Next, we independently looked for trends in PSTs' statements about CD both when they discussed selecting tasks in the abstract and when thinking about task selection in relation to their internships. We then discussed our observed trends and developed a codebook. Each transcript was randomly assigned to two authors who then completed independent coding. After independent coding, we met to examine discrepancies in codes. Once in agreement, we combined the codes into broader categories of the ways that PSTs' discussed CD. We found these categories clustered together based on context and we discussed what PST experiences (e.g. activities in the methods class or interactions with students) might be contributing to these clusters. These clusters became the general "lite" frames that describe PSTs' application of CD.

Findings

We found that PSTs operationalize CD as related to task selection differently depending on context. In situations devoid of K-12 students, like reflecting on their methods class, PSTs largely described CD in terms of math content and student understanding. In this instance, PSTs seemed to frame CD as a feature of mathematical tasks. In contrast, when reflecting on their experiences with real students, PSTs seemed to frame CD as a mediator of perceived student need. PSTs' discussion of CD

in relation to task selection shifted toward cultivating student dispositions, attending to perceived student ability, and describing problem difficulty.

Cognitive demand as a feature of mathematical tasks

In their final papers, 7 of 10 PSTs wrote about CD as a significant element of the methods course. PSTs primarily wrote about CD in two ways, (1) a way to categorize tasks and (2) as a way to support students' mathematics learning. PSTs primarily focused on contrasting the features of low and high CD tasks. For example, when reflecting on how to select tasks based on cognitive demand, Briley wrote, "We determined that the former had lower cognitive demand because it only required the memorization of the formula for area, whereas the latter required the application of area and perimeter and an explanation or argument for their thinking." Briley's explanation of CD is congruent with the descriptions provided by Smith and Stein (1998).

When analyzing tasks during the second interview, half of the PSTs linked procedural thinking and application of well-rehearsed algorithms with lower levels of CD. Carson highlighted the difference between students applying a rote procedure and conceptual understanding. He said, "[if] there's a specific way to do it, I don't think that's cognitively high. But when you have to know the whole process and what that process means, then I think that's when it's a cognitively high demanding problem." Mary Jane agreed with Carson, stating that "the fact that you need to sit and think about it, and discuss with others about it shows that there's more cognitive demand that's needed". Both Mary Jane's and Carson's focus is on the mathematical understanding required to solve a high cognitive demand problem.

Cognitive demand as a mediator of perceived student need

When talking about their placements, PSTs still connected CD to task selection in terms of student understanding of mathematics, but it ceased to be their primary focus. Instead, PSTs largely attended to perceived (1) student dispositions, (2) student ability, and (3) task difficulty. For the purposes of this report, we will focus on (1) and (2).

Eight of the ten PSTs linked student disposition to the CD of tasks. According to PSTs, CD impacts students' interest in and willingness to complete the tasks. When reflecting on her field placement, Claire articulated the connection between motivation and tasks. She stated, "I think [cognitive demand] really surfaces, and I think it really ties well into motivation too. Because if you like, if you do get something too easy, like they lose motivation, like in my mentor's class and if you give them something too hard, then they just like, give up because they don't have it." Jessica talked about students' self-efficacy and confidence as considerations for selecting tasks. She stated that selecting high CD tasks "not only promotes a growth mindset, but also lets students know that you believe they can succeed at higher-level tasks."

PSTs addressed their perception of students' ability through task selection and providing instructional supports. Participants discussed the need to find tasks that were not too easy or too hard. In terms of CD, Elizabeth described a task that was the right-fit as "It was the high end where they were challenged, but it was still low enough that they could do it." Every PST made a comment about selecting tasks that were the "right fit" for students. PSTs also discussed providing scaffolds to make tasks more accessible for students. For example, some PSTs articulated the difference between language supports for English language learners and providing mathematical supports. When selecting the right-fit the level of tasks, PSTs also wanted to prevent unproductive struggle, as opposed to looking to create productive struggle. For instance, Grace says, "Or sometimes if it is too cognitively demanding and they're getting frustrated and too flustered I think sometimes it'd be like, helpful to take a break and be like, 'okay, so maybe like, what do you guys remember about this?'" In this case, Grace thought about possible actions if students' struggle became unproductive.

Discussion

The purpose of this study is to understand how PSTs operationalize the concept of CD as they move from university coursework to working with students. Our results show that PSTs apply their conceptions of CD in context dependent ways, which is consistent with a framing perspective (e.g., Elby & Hammer, 2010; Hammer, et al., 2005). Specifically, PSTs' variance in how they operationalize CD across contexts can be understood as the activation of different resources, and subsequently different frames, as they shift from learning formally about CD to applying CD when working with students. We describe PSTs' different frames as: (1) CD as a feature of mathematical tasks and (2) CD as a mediator of perceived student need.

The frame *CD as a feature of mathematical tasks* seems to be activated when PSTs discuss tasks abstractly. PSTs perceive "what is going here" as an assessment of their knowledge of the different levels of CD. Within this frame, activated resources could include PSTs' understanding of course readings and their experiences with selecting and completing tasks in the methods course. In contrast, the frame of *CD as a mediator of perceived student need* is activated in the context of their ongoing work with students. When this frame is activated, PSTs rely more heavily on their experiences with students, rather than the formal definition of CD. Frames are a helpful way of thinking about how PST knowledge builds across contexts, rather than attributing changes in PST behavior to a "washing out" of the teacher preparation program (Richards et al., 2020). We propose that PSTs retained the formal definitions of CD but in practice their framing focused on the perceived needs and dispositions of students.

As teacher educators, we posit that examining PSTs' framing of concepts, even rough frames, can be helpful in supporting PSTs to build new resources and shift their framing (Elby et al., 2020). For example, the framing *CD as a mediator of perceived student need* was supported by PSTs' beliefs that the CD of tasks should be matched to student disposition or perceived student ability. This framing could lead to PSTs choosing tasks of low CD or lowering the CD of tasks during implementation (Stein et al., 2000). PSTs also expressed concern for supporting linguistically and culturally diverse learners' access to high CD tasks. Thus, another implication of this frame is that PSTs' perceived support of students' needs may limit opportunities for students to engage with high CD tasks (de Araujo, 2017). Teacher educators could support PSTs' development of resources and shifts in framing by revisiting the formal definitions of CD and explicitly linking them to instructional practices beyond the initial selection of the task. For example, teacher educators should explicitly model for PSTs how to support students in meeting language objectives without lowering the CD of the mathematics. When linked to student learning and dispositions, these additional experiences may become resources in PSTs' framing of CD as it relates to students' needs.

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