Pre-Service Teachers' Operationalization of Cognitive Demand

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Abstract: One year after learning about cognitive demand in a methods course, 10 pre-service teachers conceptualized the four levels (Memorization, Procedures without connections, Procedures with connections, Doing math) as either a non-discrete continuum or categorized as high, medium, or low. Among other characteristics, difficulty and length of time needed to complete a task influenced categorization which does not coincide with the formal definitions.

Introduction

Identifying and selecting tasks that promote reasoning and problem solving is an important part of mathematics teaching. Students' opportunities to engage in high-level thinking and collaborative work are contingent on teachers implementing tasks that require students to make connections between mathematical concepts (NCTM, 2014). Stein, Grover, and Henningsen (1996) define a mathematical task as "a classroom activity... to focus students' attention on a particular mathematical idea" (p. 460). A task may be a single problem or prompt, or a collection of problems and prompts. Stein and colleagues (Stein et al., 1996; Stein, Smith, Henningsen & Silver, 2000) developed a classification system that categorizes mathematical tasks on a discrete spectrum of low- to high-level cognitive demand. Cognitive demand 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 mathematics 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 cognitive demand support different learning goals, high-level cognitive demand tasks are linked to the greatest gains in student learning (Stein et al., 2000).

Considering the importance of identifying and selecting high-level cognitive demand tasks for mathematics instruction, this research examines how pre-service teachers (PSTs) distinguish between the levels of the cognitive demand of mathematics tasks: *How do PSTs operationalize cognitive demand?* Given that PSTs' initial attempts at problem-posing results in computationally focused tasks of lower cognitive demand (Crespo, 2003), cognitive demand was a central concept of the PSTs' middle grades mathematics methods course. PSTs engaged in mathematical tasks as learners and identified the tasks' levels of cognitive demand using the definitions created by Stein and colleagues (Stein et al., 1996; Stein et al., 2000).

Data and analysis

Participants included 10 PSTs pursuing certification in middle grades mathematics and science at a large Mid-Atlantic university. Cognitive demand of mathematical tasks was explicitly addressed in the methods course. PSTs were introduced to the concept of cognitively demanding tasks through the task sort created by Smith and Stein (1998). PSTs worked in groups of three to sort eight tasks into the four categories (Smith & Stein, 1998, p. 346). Then, as a class, PSTs worked together to rectify any conflicting categorizations before comparing their decisions to the classifications and justifications provided by Smith and Stein (1998). PSTs and the instructor discussed the authors' intended classifications for the tasks, while acknowledging the role that students' prior knowledge plays in determining the cognitive demand of the task. Cognitive demand of mathematical tasks was continually revisited throughout the course. The course instructor regularly modeled the enactment of rich mathematical tasks with PSTs. After PSTs completed mathematical tasks as learners, the class would debrief the task by identifying the underlying mathematics of the task, the grade-level standards addressed, the Standards for Mathematical Practice employed, and the cognitive demand.

Individual clinical interviews were conducted by the first author with PSTs a year after they were formally taught the concept of cognitive demand. PSTs were asked to categorize five tasks by level of cognitive demand and to justify their categorizations. The five tasks were selected from the casebook authored by Stein, Smith, Henningsen, and Silver (2000). These particular tasks were selected because they were similar to the task sort activity from the methods course, yet were unfamiliar to PSTs, and together represented all four categories of cognitive demand. If requested, PSTs were provided with the names of the four levels of cognitive demand (Memorization, Procedures without connections, Procedures with connections, Doing math). Transcripts of the interviews were coded for how PSTs defined the different levels of cognitive demand and the criteria they applied when assigning levels. Our poster presentation includes the five original tasks, the levels of cognitive demand of the tasks (as assigned by Stein et al., 2000), PSTs' categorizations of the tasks, and interview quotes of PSTs' justifications for their choices.

Findings

None of the PSTs used the four defined levels of cognitive demand to classify the tasks. Seven PSTs organized the tasks on a continuum of low to high cognitive demand, while three PSTs grouped the tasks as low, medium, and high. PSTs justified their assignments of cognitive demand in different ways. Half of the PSTs emphasized the difficulty or complexity of the task as an indicator of higher cognitive demand, while others suggested that the more time a task required the greater the demand. In alignment with the formal definitions of the levels of cognitive demand, half of the PSTs linked procedural thinking and application of well-rehearsed algorithms (referred to as "plug and chug" by PSTs) with lower levels of cognitive demand. Only one PST reflected on the grade level of the students, which is an important consideration of determining cognitive demand. PSTs' experiences as learners and learning preferences appear to influence their categorization of Task C, which requires the use of manipulatives. The perceived purpose of the tasks also influenced PSTs' determination of level of cognitive demand. For example, PSTs identified lower cognitively demanding tasks as warm-up problems or as occurring at the beginning of a unit, while labeling higher level tasks as a culminating activity. Overall, PSTs appear to have internalized some of the formal definitions of the categories of cognitive demand.

Implications

PSTs' construction of a continuum may be helpful when determining the level of cognitive demand from an array of tasks but not when making decisions about a single task. Within the continuum, the assigned level of cognitive demand is a result of relative demand rather than an absolute measure. Perhaps novices benefit from making such comparisons in evaluating and selecting tasks. For teacher educators, this makes the selection of examples and nonexamples in coursework particularly salient. For instance, one PST in our study referred to a task examined during the methods course as an exemplar of high cognitive demand tasks.

The continuum organization may also make it more challenging to compare tasks that address different mathematics content. Three of the five tasks addressed the concept of representing rational numbers as fractions, decimals, and percents. Every PST began by discussing these three tasks. However, there was some challenge presented when asked to compare the "fraction tasks" with tasks that addressed binomial multiplication and creating data displays. One possibility is that the content of these other two tasks is perceived as being more difficult, regardless of how the task is presented or the type of mathematical thinking required. Thus, when PSTs conflate "difficulty" with higher cognitive demand they may select inaccessible tasks for their students, when they intend to provide those with high cognitive demand.

References

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