HOW ATTEMPTING TO BUILD ON STUDENT THINKING INFLUENCES THE SCAFFOLDING TEACHERS PROVIDE DURING ENACTMENT OF HIGH COGNITIVE DEMAND TASKS

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We used videotaped enactments of high cognitive demand tasks to investigate whether teachers who were engaged in the teaching practice of building*—and thus were focused on having the class collaboratively make sense of their peers' high-leverage mathematical contributions—provided scaffolding that supported the maintenance of high cognitive demand tasks. Attempting to build on high-leverage student thinking seemed to mitigate the teachers' tendencies to provide inappropriate amounts of scaffolding because they: (1) believed the building practice required them to refrain from showing the students how to solve the task; (2) wanted to elicit student reasoning about their peer's contribution for the building practice to utilize; and (3) saw the benefits of their students being able to engage in the mathematical thinking themselves.*

INTRODUCTION

Research has shown the advantages of teaching practices that use student thinking (e.g., Carpenter & Fennema, 1992), the importance of using high cognitive demand tasks, and the need to maintain high levels of cognitive demand during task enactments to maximize their benefits (e.g., Stein & Lane, 1996). Research has also identified several factors that support the maintenance of high cognitive demand, including the appropriate use of scaffolding (Stein et al., 1996). Recent attention has been directed toward articulating specific teaching practices that use student thinking. For example, the MOST Research Team has focused on articulating the *teaching practice of building* (e.g., Leatham et al., 2022), a teaching practice designed to take full advantage of MOSTs (Mathematical Opportunities in Student Thinking)—high-leverage student mathematical contributions that provide an in-the-moment opportunity to engage the class in joint sense making about that contribution to better understand the important mathematics within it. Better understanding the interaction between teaching practices that use student thinking and the maintenance of cognitive demand will support leveraging the known abilities of both to support student learning. We contribute to this understanding by investigating how teachers' attempts to engage in the teaching practice of building affected the scaffolding they provided during their enactments of high cognitive demand tasks.

LITERATURE REVIEW

The MOST Research Team has defined the *teaching practice of building* (henceforth referred to as building) as making a student contribution "the object of consideration

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by the class in order to engage the class in making sense of that thinking to better understand an important mathematical idea" (Van Zoest et al., 2017, p. 36). They describe building as being comprised of four elements: (1) establish the student mathematics of the [contribution] as the object to be discussed; (2) grapple toss that object in a way that positions the class to make sense of it; (3) conduct a whole-class discussion that supports the students in making sense of the student mathematics of the [contribution]; and (4) make explicit the important mathematical idea from the discussion (Leatham et al., 2021, p. 1393)

Their work to articulate the key aspects of each element has relied on an iterative process involving teacher-researchers (TRs) who enacted the team's evolving conceptions of building in their classrooms (Leatham et al., 2022). The TRs did this using a set of high cognitive demand tasks designed to elicit predictable MOSTs that the TRs could prepare to build on (see Figure 1).

(a) Percent Discount	**(b) Variables**
The price of a necklace was first increased 50% and later decreased 50%. Is the final price the same as the original price? Why or why not?	Which is larger, x or $x + x$? Explain your reasoning.

Figure 1: Two tasks used by the teacher-researchers.

Cognitively demanding tasks are challenging problems, or sets of problems, that require students to use their existing knowledge, sometimes in new and unique ways, along solution pathways that are not immediately clear (Stein et al., 1996). The use of such tasks has been shown to lead to student learning gains (Stein & Lane, 1996). Unfortunately, the high cognitive demand of these tasks is not maintained in many lessons that begin with cognitively demanding tasks (Henningsen & Stein, 1997). As a result, much work has been done to understand the complexity of maintaining high levels of cognitive demand during task enactments. For example, drawing from 520 task enactments, Stein et al. (1996) identified factors that maintain and lower cognitive demand. These factors have been utilized by numerous studies (e.g., Estrella et al., 2019) to better understand the maintenance of cognitive demand.

Providing appropriate scaffolding is one of Stein et al.'s (1996) factors that help maintain cognitive demand. They determined that teachers or more capable peers offering appropriate scaffolding occurred in 58% of tasks where cognitive demand was maintained during set up and implementation. Henningsen and Stein (1997) looked specifically at tasks that began as the highest category of cognitive demand—doing math—and determined that appropriate scaffolding was offered in 73% of such tasks for which the cognitive demand was maintained. *Challenges become nonproblems* is one of the factors that Stein et al. (1996) found to cause cognitive demand to be lowered. The reasons they give for this happening included the teacher "specifying explicit procedures or steps to perform" or "either performing [the challenging aspects of the task] or telling them how to do them" (Stein et al., 1996, p. 479)—that is, providing inappropriate scaffolding. Inappropriate scaffolding was found in 64% of enactments where cognitive demand was lowered, regardless of the starting level of the tasks (Stein et al., 1996), and in 39% of enactments where cognitive demand was lowered for doing math tasks (Henningsen and Stein, 1997). Thus, it is clear that scaffolding is an important factor in both the maintenance and decline of cognitive demand during task enactments.

Smit and colleagues (2013) conceptualized the idea of scaffolding for whole-class settings. In their work, as is typical, scaffolding is generally described as a positive contributor to student learning. The research on the maintenance and decline of cognitive demand, however, suggests that the nature of the scaffolding matters. For example, a common scaffolding strategy is to give students a worked example of a similar problem. In the context of working with a high cognitive demand task, however, this is likely to undermine the goals of the task because it provides the students with a specific strategy for solving the task, and thus lowers the cognitive demand. Teachers who are engaged in the teaching practice of building are focused on having the class engage in making sense of MOSTs—high-leverage contributions made by their peers—and thus may be focused on providing scaffolding that is more compatible with the maintenance of high cognitive demand tasks. By considering scaffolding through the lens of cognitive demand, we can draw from previous work to better understand how the scaffolding that teachers provide during task enactments may have been affected by their attempt to engage in the building practice.

THEORETICAL FRAMEWORK

Our investigation of scaffolding takes a participationist approach (Vygotsky, 1987). That is, we see student learning as taking place through students' interactions with more knowledgeable others, such as the teacher and their peers. As discussed in Sfard and Cobb (2022), this approach acknowledges several important aspects of instruction: the tasks used; the engagement of students with the tasks, both individually and through class discussion; the teacher as the knowledgeable other who facilitates the learning; and the teacher's mathematical knowledge for teaching. Thus our decision to use high cognitive demand tasks with accompanying task notes that provided guidance in these areas. For example, the notes provided common student responses to the tasks, identified which student contributions were likely to be MOSTs and provided suggested questions to ask at different points in the enactment to facilitate students' understanding of the embedded mathematics. We use a broad definition of scaffolding "as an interactional process between a person with educational intentions and a learner, aiming to support this learner's learning process by giving appropriate and temporary help" (van Oers, 2014, p. 535). Thus, we considered a teacher move to be scaffolding if there was evidence through what the teacher did or said that they were "aiming to support" the students' learning of mathematics with their actions. We used the cognitive demand framework (Stein et al., 1996) to determine whether the scaffolding provided was appropriate.

METHODOLOGY

Six middle school teacher-researchers (TRs) in the larger MOST project focused on conceptualizing the teaching practice of building (for more details, see Leatham et al., 2022) provided 24 videotaped classroom enactments of the tasks in Figure 1 (each teacher enacted each task twice), 6 online teacher surveys, and 5 recorded online teacher interviews (one teacher was not available). We first analyzed the videotaped task enactments using the **R**eorganized Factors that **U**ndermine or **K**eep Cognitive Demand (RUK; Ruk, 2020), a succinct tool designed to consistently measure the factors that maintain and lower cognitive demand (as identified by Stein et al., 1996). The "Amount of Scaffolding" category of the RUK looks at how much scaffolding was offered on a continuum from 1 to 4, with 4 representing task enactments with scaffolding that supported students without taking away necessary struggle. We next developed the survey that we administered to the TRs based on the findings from the RUK analysis. For example, to better understand scaffolding we asked this question: "In general, after you present an example or other information to your classes, how is what you presented related to the problem(s) that you assign your students afterwards?" Then we developed the interview questions for the TRs based on the results of the RUK and their individual survey responses. For example, if the results showed that a TR offered different scaffolding than usual, they were asked: "To what extent did [attempting to enact the building practice] change the amount of scaffolding that you normally offer (as opposed to other problems that you give your students)." This process of analysis followed by additional data collection allowed us to engage in the three levels of quantitative data analysis described by Simon (2019).

RESULTS

Attempting to engage in the teaching practice of building seemed to have a positive effect on the scaffolding teachers provided during their enactments of high cognitive demand tasks. The RUK showed that 23 out of the 24 task enactments (96%) had appropriate scaffolding throughout the enactment, and the remaining enactment had appropriate scaffolding at the beginning of the enactment. Contrast this with Henningsen and Stein's (1997) study of tasks of high cognitive demand, where they found appropriate scaffolding in only 73% of the enactments. To better understand the relationship of the scaffolding teachers provided to their enactment of the building practice, we turn to the interviews, where two teachers illustrated how they did a little less scaffolding than they normally do, one described how they did a lot less scaffolding, and two explained how they did the same amount of scaffolding. One of the two teachers who said that they offered a little less scaffolding gave an example of the scaffolding they would have offered for the Variables task (see Figure 1b) if they hadn't been attempting to engage in the building practice. They said that they "would have started a little bit with a conversation about what is a variable, and what different ways a variable can be used." However, this teacher recognized that offering this scaffolding "takes away from the mathematics that [the students] experienced as they went through [the task]" and, because they believed that experiencing this mathematics was needed for the building practice, they did not offer this additional scaffolding. If the teacher had offered this scaffolding before students began grappling with this task, cognitive demand would likely have been lowered significantly. Students would have, as part of the scaffolding, discussed and likely resolved ideas related to the underlying mathematics of this task—that all possible values within a domain must be considered to determine relative values of variable expressions—before they had the opportunity to engage with these ideas themselves through exploration of the task. Thus, it seems that this teacher offered an appropriate amount of scaffolding because they believed that it was a necessary part of the building practice.

The other teacher who said that they offered a little less scaffolding, revealed during their interview that for the Variables task, if it had not been for enacting the teaching practice of building on student thinking, they "might have given [the students]: try it with two positive numbers, try it with two negative numbers, you know, can you generalize what happened." This scaffolding would have lowered the cognitive demand of this task because students would have lost the opportunity to explore for themselves and discover that positive and negative numbers (as well as zero) lead to different outcomes for this task, which in turn leads to uncovering the underlying mathematics. This teacher also said that before understanding the practice of building on student thinking, "I would have [scaffolded] right away." But now, I'd wait and "if I didn't see that there was going to be a good discussion then I might say, okay why don't you guys try it with different types of numbers and see what happens." This teacher believed that the mathematics "actually will make more sense to them because they came up with those ideas, it wasn't me telling them, oh you were wrong see here's your counterexample. You know, that they can kind of, like, work through that muddiness themselves, and come out hopefully with a more clear picture." Through attempting to engage in the building practice, this teacher came to see the value in allowing students to productively struggle in their classroom, not just in service of the building practice, but in general as well.

The teacher who said they offered a lot less scaffolding, revealed in her interview that if it had not been for enacting the teaching practice of building on student thinking, and wanting "all of those different misconceptions to come out," they would have started the Variables task by asking their students to think "about different numbers. Like, make sure you think about all the numbers, or something like that." Although this is not as explicit as telling students to consider positive and negative numbers, it would have likely had a similar effect of lowering the cognitive demand of this task because students would have been given clues about the underlying mathematics before they started grappling with the task. Thus, it also seems that the desire to draw out student thinking when enacting the building practice can improve the scaffolding offered during the use of high cognitive demand tasks.

One of the two teachers who said they would have offered the same amount of scaffolding offered an appropriate amount of scaffolding during their enactments. This teacher had an extensive knowledge of cognitive demand research, and said that this research, “made a huge impact on me, and my practice” and that “I think it's extremely important that students are engaged and doing significant math and working at a high level.” This teacher was immersed in applying cognitive demand research in their classroom and thus was already focused on continuously attempting to provide an appropriate amount of scaffolding.

The other teacher offered inappropriate scaffolding in one of their enactments by working through a specific example that broke the problem down into smaller steps, and then asking students for only small bits of information, such as simplification of expressions or what specific numbers represented—a type of questioning pattern that Wood (1998) identified as funneling. Also, rather than letting students work through incorrect ideas by asking follow-up questions, the teacher said “no,” and waited for correct thinking to emerge. These actions run contrary to the practice of building because, although the interaction began with the student’s thinking, the attention quickly shifted to the teacher’s way of thinking. These teacher actions removed the challenge from the task by breaking it down into smaller parts, controlling the conversation, and only moving forward when students shared the correct thinking that the teacher was looking for. Fortunately, the teacher did this towards the end of the enactment, so the students had time to grapple with the task before the cognitive demand was lowered. Had the teacher provided this scaffolding earlier in the enactment, cognitive demand likely would have been lowered even more. To gain an understanding of why cognitive demand was lowered in this way, we look again at our interview data.

During their interview, this teacher realized that offering the scaffolding that they did ran contrary to the building practice—that they had gone too far and had given too much information away to their students. The teacher also noted that if they had not been enacting the practice of building on students’ thinking, they likely would have worked through an example like this much earlier in the class discussion but held off because they believed that enacting the building practice required more time for students to work through this task on their own. Furthermore, if it hadn't been for enacting the building practice, she likely would have lowered the cognitive demand even further than she did by offering this scaffolding earlier and giving her students even less time to productively struggle with this task. So, even though she did not adhere to the guidelines of the practice, this teacher still maintained a higher level of cognitive demand than if she had not been attempting to enact the building practice.

Considering the cases described above, the results of applying the RUK, and the survey and interview data, we can conclude that the teachers in this study were able to recognize appropriate scaffolding for enacting a high cognitive demand task. However, even though they can recognize this, they may still offer scaffolding that takes away the need for students to make sense of the mathematics in the task, and thus lowers the cognitive demand of the tasks that they are enacting. Attempting to build on student thinking seemed to mitigate the teachers’ tendencies to provide inappropriate amounts of scaffolding for three reasons: (1) they believed the building practice required them to hold back from showing the students how to solve the task: (2) they wanted to elicit student reasoning about their peer's contribution for the building practice to utilize; and (3) they saw the benefits of their students being able to engage in the mathematical thinking themselves.

DISCUSSION

Our findings showed that the teachers in this study were able to recognize appropriate scaffolding. Indeed, almost unanimously they provided appropriate scaffolding for every task they enacted as part of this study. However, even though they could all recognize, and successfully provide appropriate scaffolding, most of them noted that they would have offered more scaffolding had they not been enacting the building practice. Furthermore, if they were all to provide the scaffolding that they described in their interviews, they almost assuredly would have lowered cognitive demand for their task enactments. However, it seems that if teachers have a specific reason (e.g., attempting to enact the building practice, or a belief in the importance of maintaining cognitive demand), they can, and do, provide scaffolding that supports student learning.

Since teachers can recognize appropriate scaffolding and provide it if they try, it seems that what they need is a reason to do so. In our study, attempting to engage in the building practice provided that reason. Other specific teaching practices may also provide reasons for offering appropriate scaffolding and thus support the use of scaffolding to maintain high cognitive domain. As such, future research to better understand the influence of specific teaching practices on the scaffolding teachers provide during enactment of high cognitive demand tasks could compare teachers who simply enact a task with teachers who try to engage in a teaching practice that prompts them to consider the scaffolding they should offer when enacting that same task. Future research could also investigate whether teachers who have improved the scaffolding they provide when engaged in a particular teaching practice, such as building, extend that appropriate use of scaffolding to their teaching more broadly.

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