2016 NCTM RESEARCH CONFERENCE
April 11-13 • San Francisco

Paper Title: Maintaining High Levels of Cognitive Demand through Student Silence
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Session Title:
Session Type: Brief Research Report
Presentation Date: April 13th, 2016
Presentation Location: San Francisco, California

Introduction

Student engagement in high-level cognitive tasks and verbal prompts has led to large gains in student achievement (Boaler & Staples, 2008; Stein & Lane, 1996). However, Stigler and Hiebert (2004) state that teachers do not commonly maintain high cognitive demand during instruction and many prompts end up diminishing high levels of cognitive demand. Moreover, Gal, Lin, and Ying (2009) found that many teachers struggle with maintaining high cognitive demand in moments of student silence. Research is lacking instructional tools that help move teachers past these moments of silence without giving up on cognitively demanding tasks or prompts (Gal et al., 2009). Since student silence presents a major area of struggle for many teachers (Leinhardt & Steele, 2005), further investigations that support practices that maintain high-level cognitive demand are pivotal in ensuring dialogical success (Wilhelm, 2014).

These ideas and previous research have led us to the following research questions: When a teacher aims to re-engage students in discourse after no student response to the initial prompt (henceforth, silence):

1) What types of prompts typically lead to maintained or raised cognitive demand when compared to the initial prompt?

2) What characteristics are common within and between types of prompts that are successful in maintaining or raising cognitive demand?

Theoretical Framework

The Common Core State Standards Initiative (CCSSI, 2010) and researchers continue to discuss the interactive nature of learning, which aligns with social constructivist views (Von Glasersfeld, 1989; Windschitl, 2002). Constructivists believe that when a learner experiences a mathematical pattern or problem they must be given the opportunity to actively construct their own mathematical meaning, and when they reach a point where their own knowledge is not enough to move them forward, the role of classmates and the teacher becomes pivotal. When students are silent, teachers have no way of knowing whether students' understandings align with their own. This theoretical view highlights the importance of teachers' ability to prompt students to explore and explain ideas more deeply themselves.

Methods

This case study of three middle school mathematics teachers took an interpretivist approach in looking at how specific teacher prompts can re-engage students in mathematical discourse after moments of student silence (Merriam, 2009). Multiple interviews were conducted and six class periods were observed for each teacher, giving a total of eighteen observations. Our unit of analysis was prompt sequences that involved moments of total student silence (Molinari, Mameli, & Gnisci, 2013). A sequence begins with an unanswered prompt and ends once students re-engaged in discourse about any prompts within the sequence, or the teacher answered the prompt by him or herself. Field notes and interviews were also used for triangulation of the data.

Data analysis

Three coders used both transcripts and video to assure accuracy when coding data using the combined frameworks of Drageset (2013) and Stein et al. (1996). After moments of student silence were identified, Drageset's (2013) framework was used to code and analyze the type of prompt; which lists thirteen different prompt types, which fall under three categories: Progressing Actions, Focusing Actions, and Redirecting Actions. The Stein et al. (1996) framework helped identify four levels of cognitive demand: 1) Memorization or recall of a fact, 2) use of procedures and algorithms without attention to concepts or understanding, 3) use of procedures and algorithms with attention to concepts or understanding, and 4) "doing mathematics," which consists of employment of complex thinking and reasoning strategies such as conjecturing, justifying, interpreting. Levels 1 and 2 are considered low-level cognitive demand, and 3 and 4 are considered as high.

To ensure reliability, all three coders coded the first nine class periods together. Once coders built a solid understanding of the framework, the last half of the data was coded in pairs. Any disagreements in coding were discussed until all coders reached an agreement. Final agreement was reached on 100 percent of the codes.

Coders then classified teacher prompting sequences as one of four types: a) maintained high levels of cognitive demand, b) raised from low to high levels of cognitive demand, c) lowered cognitive demand from high to low levels, or d) maintained low levels of cognitive demand. Coders analyzed relationships within specific prompt types, and within different sequence types. Specific characteristics and patterns that maintained high levels were then explored.

Results

Table 1 lists the number of prompt sequences that raised cognitive demand to higher levels, maintained high levels, the total number of prompts, and percentages for each teacher. Percentages listed under the total number of prompt sequences represent the percentage of teacher prompts that raised or maintained high levels of cognitive demand.

Table 1

Teacher Prompts that Raised or Maintained Cognitive Demand

Teacher	Raised	Maintained	Total	% Raised or Maintained
#1	3	9	50	24%
#2	5	25	57	52.6%
#3	3	15	42	42.9%

Table 1

Types of Prompts to Maintain and Raise Cognitive Demand

Table 2 shows the results of coding in terms of teachers' prompts and cognitive demand. Each number in the table represents the number of sequences that fell within that specific prompt type and level of cognitive demand. All teachers tend to use more focusing actions than progressing actions. Progressing actions tend to lead to maintenance of low cognitive levels, while focusing actions typically enable higher levels of cognitive thinking. There were not enough redirecting actions to signify any patterns.

Table 2

Prompt Type and Maintenance of Cognitive Demand

		Teacher 1		Teacher 2		Teacher 3	
Low vs. Maintained/Raised CD		L	M/R	L	M/R	L	M/R
Progressing Actions	Demonstration	1	-	7	3	-	-
	Simplification	6	2	4	-	4	3
	Closed Progress Details	2	1	3	2	11	-
	Open Progress Detains	5	-	1	2	1	1
Focusing Actions	Enlighten Details	6	7	1	5	3	3
	Justification	-	-	-	1	-	1
	Apply to Similar Problems	1	1	1	6	-	6
	Notice	10	1	6	5	3	2
	Recap	3	-	-	2	1	2
	Request Assessment	2	-	1	2	1	-
Redirecting Actions	Correcting Questions	1	-	3	2	1	-
	Advising a New Strategy	1	-	-	-	-	-
	Put Aside	-	-	-	-	-	-

Table 2

Focusing Actions. Two main types of prompts that were mostly used in maintaining high level cognitive demand were Enlighten Details and Apply to Similar Problems. Based on our observations, these prompt types focus students' attention to conceptual understanding and application, such as provoking students to interpret and explain mathematical meaning by recalling their prior knowledge.

The use of Justification prompts also led to maintained high level cognitive demand, however, only two prompts of this type were found. The nature of Justification prompts led us to believe that it maintained or raised high level cognitive demand because they asks students to explain or justify why an answer or method is correct.

Progressing Actions. One noticeable finding was that teacher 2 tended to use a lot more Demonstration prompts than the other two teachers. However, the cognitive demand for these prompts were at both ends of the cognitive spectrum. Demonstration prompts were frequently high-level when the teacher was discussing a conceptually based task, and low-level when a more procedural task was the focus.

Characteristics of Successful Prompts

Two types of prompts led to maintained high cognitive demand: Enlighten Details and Apply to Similar Problems. Across all three teachers, the Enlighten Details prompts encouraged students to recall important conceptual aspects of mathematical concepts that were previously learned.

The prompt type “Apply to Similar Problems” typically led to maintained high cognitive demand across all teachers. In general, teachers tended to create more than one question that applied to other problems and required students to interpret meaning from a real-life context.

Between Enlighten Details and Apply to Similar Problems, there were noticeable trends in ways they maintained high cognitive demand. Many of such prompts asked students to apply prior knowledge to new mathematical notation, vocabulary, or procedures. Another commonality was that these prompts encouraged students to interpret meaning from problems, which gave them opportunities to make sense of mathematical concepts.

Conclusions

Generally, prompts that were successful in raising or maintaining high levels of cognitive demand after student silence were embedded within a real-life context and included questions that were aimed at understanding mathematical concepts. If prompts started as procedural, teachers were able to raise the cognitive demand by asking questions about the meaning of mathematical ideas.

Although past research has already examined the types of prompts teachers use to engage students in discourse, this study's implications contribute to current research by exploring prompt types that are successful in engaging students in high-level thinking and communication. Based on these findings, three main prompt types could be used to help teachers move past student silence without diminishing high levels of cognitive demand: Enlighten Details, Apply to Similar Problems, and Justification. The low prevalence of the justification prompt type may show an untapped resource for teachers. Since promotion of high cognitive demand opportunities in the classroom can help students develop a deeper understanding of concepts (Boston & Smith, 2009), these prompt types could be emphasized in professional development sessions as well as pre-service teacher training.

One limitation with our study was that the frequency of moments of silence might have a positive correlation with opportunities to respond, possibly inflating the results depending on the teachers' method of instruction. Another limitation was that the Stein et al. (1996) framework did not account for the cognitive demand of making connections between mathematical vocabulary. Based on the current framework, many vocabulary prompts were coded as lower level even though there were instances where teachers made connections to real-world contexts so students could make connections to mathematical vocabulary. A modified framework that includes these connections as more than just recall might be explored.

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