CHANGE IN POSING OPPORTUNITIES TO LEARN IN THE CONTEXT OF PROFESSIONAL DEVELOPMENT

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We apply the commognitive framework to exame changes in instructional practices of a teacher participating in the TEAMS (Teaching Exploratively for All Mathematics Students) professional development (PD) program. Specifically, we focus on the process that has often been named "lowering of cognitive demand". We conceptualize this lowering as "ritualization" of OTLs: transitioning from exploration-requiring Opportunities to Learn (OTLs) to ritual-enabling OTLs. Two lessons of one elementary school mathematics teacher who participated in the PD for two years are compared. Findings show a quantitative change in OTLs, as well as change in patterns of "ritualization"- transitions from exploration-requiring to ritual-enabling OTLs.

INTRODUCTION

Over the past several years, "powerful", cognitively demanding or "explorative" mathematics teaching has received widespread interest (Schoenfeld, 2014; Smith & Stein, 2011; Heyd-Metzuyanim, Smith, Bill, & Resnick, 2018). This type of instruction attempts to minimize the memorization of rules and procedures and to encourage the learner to struggle with cognitively demanding tasks, accompanied by discussions in which the students develop their mathematical thinking. Yet, despite the enormous amount of resources put into professional development for such cognitively demanding instruction, studies show that mathematics classrooms around the world often pose mainly ritual opportunities to learn (Nachlieli & Tabach, 2018). One of the main processes that may underlie this situation, especially in cases where the curriculum and the tasks afford explorations, is the phenomenon known as "lowering of cognitive demand" (Stein & Smith, 1998). Stein and Smith (1998; Smith & Stein, 2011) showed that this phenomenon is extremely widespread. Yet, the mechanisms underlying it are not yet sufficiently understood. In this study, we apply the commognitive framework (Sfard, 2008; Nachlieli & Tabach, 2018) to examine the discursive characteristics of the process of lowering cognitive demand, and how it can change over the course of a teacher engaging in professional development.

THEORETICAL BACKGROUND

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The commognitive framework conceptualizes learning as a process by which learners move from enacting ritual routines, where procedures are imitated rigidly and performed for the sake of others, to explorative routines, where procedures are picked up flexibly for the sake of producing a certain mathematical narrative (Lavie et al.,

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2018). Teaching can offer students opportunities for enacting ritual routines or explorative routines. Nachlieli and Tabach (2018) defined the actions of the teacher that enable students to follow explorative vs. ritual routines as two distinct types of opportunities to learn (OTLs). Ritual enabling OTLs are teachers' actions that provide students with a task that can be successfully performed through rigid application of a procedure that had been previously learned. Exploration-requiring OTLs create a situation where students are required to produce mathematical narratives based on formerly established narratives and on their own authority. In exploration-requiring OTLs, there is no possibility of simply following previously learned procedures to satisfy the requirement of the task. Something new, even if very specific, needs to be conjured up by the student.

Multiple studies have shown that the practice of "ritualization", which we define as turning exploration-requiring OTLs to ritual-requiring OTLs, is wide-spread (McCloskey, 2014). Stein and Smith (1998) have termed it "lowering of cognitive demand", showing that often tasks that start out as posing multiple opportunities for explorations, end up as constrained to demanding only imitation of previously learned procedures. As a result of this observation, Smith and Stein (2011) came up with a PD program named "the five practices for orchestrating productive discussions" which is intended to help teachers avoid the lowering of cognitive demand. This program includes various teaching routines such as launching a task, assigning students to work in groups, calling them to the board to present their solutions and linking between them. Previous studies have shown that although the "5 Practices" are often accepted with much enthusiasm by teachers, the realities of changing discursive practices in wholeclassroom discussions are complex and not sufficiently understood (Heyd-Metzuyanim, et al., 2018). Their examination necessitates a discursive approach, which helps delineate the exact interactional processes that occur between the teacher and the student as this "lowering of cognitive demand" occurs. For this, the commognitive approach, which combines conceptual tools for looking at interactional and mathematical aspects of the discourse, is particularly useful.

According to Sfard (2008), routines are enacted in mathematics to produce endorsed narratives about mathematical objects or mathematical signs. Endorsed narratives are texts that are accepted as truths by the relevant community. Routines are identified by three distinct parts: initiation, procedure and closure.

Our research question is thus: how does the process of ritualization (turning from explorative-requiring to ritual-enabling OTLs), as identified in the teaching of one teacher, change in the lessons of that teacher after professional development?

RESEARCH METHODS

This study was based on a case of a teacher we shall call Simone. Simone was an experienced teacher (around 27 years of experience in teaching mathematics) and was

usually teaching the higher grades of elementary school. She participated in the PD for two years, where this PD included around 60 hours of group instruction in a teachers'district center, accompanied by 60 hours of individual work on lesson planning, implementation and reflection. Parts of these individual-work hours were allocated for the coaching of the first author (who was also the PD instructor) with individual teachers who volunteered for the study. Simone received around 6 hours of such coaching, including lesson planning, observation of her lessons and a feedback session. For the close analysis of the present study, Simone was chosen out of 30 teachers whom we have videotaped data on, since we got the impression, both by observations and by more macro-scale evaluation tools, that some aspects of her practice have changed. Yet despite this general impression, it was difficult to pinpoint what precisely had changed in Simone's teaching.

From the eight lessons that Simone taught and videotaped, two lessons were chosen for comparison - the first and the last. Both lessons took place with the same class, the first during December 2016 in Fifth Grade and the second during February 2018 in Sixth Grade. The tasks in both lessons were identified by us as cognitively demanding, requiring students to reason and form generalizations. The similarity between the tasks, their levels of cognitive demand, goals, visual mediators, and lengths created a good basis for comparison, which is essential for a micro-analysis.

Analysis

In order to identify exploration-requiring OTLs, the analysis was carried out in three stages. The first stage followed the method described in Nachlieli & Tabach (2018), and segmented the lesson to routines and sub-routines of OTLs. Generally an OTL opened up with a question or a prompt made by the teacher. Often, this question or prompt was rephrased by the teacher into another question, which consisted of a prompt for a sub-routine: a procedure that needs to be followed in order to produce the original routine. Routines were numbered using whole numbers (1, 2, etc.) while sub-routines and sub-routines were numbered 1.1, 1.1.1 respectively.

The second stage of the analysis was intended to illuminate the nature of each of the narratives that the routines and sub-routines were intended to produce. This was imperative for determining the explorative vs. ritual status of the OTL, as will be detailed in the next section. For categorizing the narratives, we turned each of the teacher's prompts into an "expected narrative". An expected narrative is a narrative that is most likely to be received as a result of a teacher's question or prompt. For example, if the teacher asked "how many squares are there here?" and pointed to a picture with 4 squares, the expected narrative would be "there are 4 squares here". Since we do not have access to the teacher's or students' expectations, we interpreted the expected narratives according to the context and to what would be reasonable for a student to imagine as an acceptable response. After coupling teachers' questions into "expected narratives", we turned to describe the students' replies as "received narratives". This produced two outcomes: one was a clear blue-print of the structure of the OTLs in terms of expected and received narratives. The second was a clear operationalization of ritual vs. explorative OTLs. This led to the third stage of analysis, which consisted

of mapping OTLs to exploration-requiring vs. ritual-enabling. Exploration-requiring OTLs were defined as teachers' prompts in which there were several (if not infinite) possible expected-narratives that could be derived from the prompt. Ritual-enabling OTLs were defined as prompts where the expected narrative was limited and well-defined. Exemplification of this analysis will be presented in the findings section.

FINDINGS

Our first finding concerns a quantitative comparison of the ritual and explorative subroutines in each of the lessons (see Figure 1). This comparison shows change between the first and second lesson in the number of exploration-requiring and ritual-enabling OTLs. For the current comparison, we counted only OTLs occurring during the wholeclassroom discussion. Therefore, the routine numbers (A4-A7, B4-B7) in Figure 1 start from 4. Whereas in the first lesson there were 18 exploration-requiring OTLs and 33 ritual-enabling OTLs, in the last lesson there were 20 exploration-requiring and only 10 ritual-enabling OTLs. We note that a high number of OTLs is not necessarily a good sign, since it often shows that the teacher asked many questions and did not give enough time for students to respond. Thus, a rise of the ratio of explorative to ritual OTLs (from 18:33 to 20:10), together with a lowering of the total number of OTLs (from51 to 30) shows a substantial change in the overall opportunities given to students to participate and contribute substantial mathematical narratives during the discussion.





The Transition from Exploration-Requiring to Ritual-Enabling OTLs

After mapping the OTLs, we examined all the situations in which the teacher opened up the routine or subroutine with an exploration-requiring OTL and followed this by switching to ritual-enabling OTLs. We found these situations to be generally characterized by the student failing to come up with one of the expected narratives that would be deemed as acceptable under the exploration-requiring OTL. This either happened when the students showed confusion with relation to the teachers' requests, or when they produced an answer that was not sufficiently clear (as perceived by the teacher) for other students to hear.

Squares and Perimeters

Build polygons from squares so that each square has at least one side shared with the neighboring square. For example:



Find all the possibilities for organizing 3 squares. What is the arrangement with the biggest perimeter? What is the arrangement with the smallest perimeter? Find different polygons made with 4 squares ... with 5 squares.... Continue to 6 squares and more.

Figure 2 – the Squares and Perimeters task used in Lesson 1

For example, Table 1 shows the deterioration of an exploration-requiring OTL, where the teachers invited students to raise hypotheses regarding why they were asked to "continue on and on" with examining different square-configurations and their perimeters (see figure 2).

The expected narratives that could be produced as response to this prompt were various, including narratives about the arrangements producing the lowest and highest perimeters, which were probably what the teacher was after. The received answer, however, was rather limited. One student said "to find a rule". The teacher thus opened another explorative OTL (6.1) asking "how do we receive a shape with a large perimeter?" Although the possibilities for answering this question were more constrained, we still categorize this OTL as exploration-requiring since there are a variety of narratives that could be deemed as acceptable, all concerning the ways by which one could "receive the larger perimeter". Not having heard an acceptable answer to this question, the teacher quickly moved to an even more constrained question, this time, providing a ritual-enabling OTL (6.2): "What is common to all these arrangements I have here, that are built from 5 squares?".

Narratives expected/ received in Lesson 1, Routine 6

6. Expected: a variety of narratives concerning the connection between the squares' arrangement and their perimeter

6. Received: (We were asked to continue on and on so that we find) a rule

6.1 Expected: variety of narratives regarding the relation between the shape and the largest perimeter

6.1 Received: inaccurate answer

6.2 Expected: All arrangements (on the board) are built of 5 squares and their area is equal

6.2 Received: Student remains confused

6.2.1 Expected: All the shapes have the same area

6.2.1 Received: The shapes are built from 5 squares

Legend:

Exploration-requiring

Ritual-enabling

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Table 1: Mapping OTLs according to Expected/Received narratives

Now the only acceptable answers would be quite constrained, falling under the narrative "they all have the same area". Since the students still did not produce the expected answers, the teacher continued posing this question in slightly different wordings (6.2.1), until she got the narrative that "all shapes are built from 5 squares". The above analysis was performed on all routines and sub-routines of the whole-classroom discussion. It revealed a more precise view of the ways by which the teacher changed her discursive practices around presenting OTLs from the first to the last lesson. Figure 4 shows a bird's-eye view of the change in ritual-enabling and exploration-requiring routines and sub-routines of two particular routines that we found the most amenable for comparison. The first routine is Ls1.routine 6, which was partially described above and in table 1. The second was a routine from the last lesson, which had a very similar function: Simone attempted to elicit from the students an explanation regarding how they had solved the S patterns problem (see figure 3).



Figure 3 - The S task implemented in the last lesson

The routine occurred after one student had already presented his group's solution, which could be algebraically described as (n+1)(n-1)+2. The teacher, having monitored the students while working in groups, probably expected the group of girls she was inviting to the board to produce an alternative narrative which could be summarized as n*n+1. Yet, similarly to the first lesson, the students were unable to articulate their reasoning once invited to the board. This situation produced, in the first lesson, an immediate deterioration into a series of ritual OTLs. In the last lesson, however, as can be seen by the recurrence of exploration-requiring OTLs, the teacher went back and forth more flexibly between explorative-requiring and ritual-enabling OTLs. The ritual-enabling OTLs consisted of prompts encouraging the students to explain their solution to the 3^{rd} structure (using the $3 \times 3 + 1$ calculation), yet immediately went back to requesting the students to explain their general solution, which provided an explorative-requiring OTL.

Importantly, the two teaching routines produced very different results, in terms of end narratives. Ls1.Routine 6 ended up in a narrative that was quite peripheral to the goal of the routine (*square cm are used to calculate area*). In fact, the whole lesson never produced a clear narrative regarding the connection between the shape of the squares and the perimeter. In contrast, Ls8.Routine 6 ended up with an acceptable mathematical

narrative regarding the appropriateness of the girls' solution $((n + 1)(n - 1) + 2 = n \times n + 1)$. Although this narrative, in its algebraic form, was beyond the reach of most of the classroom, it enabled the teacher to further explain the two forms of generalizations produced by the students.



Figure 4 – "Birds eye" view of the patterns of Exploration-requiring and Ritual-Enabling OTLs in Simone's first and last lessons

We thus see a clear change in the ways by which the teacher handled situations that had originally, in her first lesson, produced deterioration into ritual-enabling OTLs. In the first lesson, the teacher's ritualization moves produced, gradually, partial narratives that became more and more peripheral to the main narrative that she wished to elicit from students. This main narrative was "the more elongated the shape of the squares, the bigger is the perimeter, while the more 'condensed' the shape is, the smaller the perimeter becomes". Instead of producing this narrative, her gradual production of OTLs that were more and more ritual-enabling, produced partial narratives such as "square cm measures area". In the second lesson, we did not see such "breaking up" of the main narrative into partial and meaningless sub-narratives. Instead, there was a back-and-forth movement between narratives about particular mathematical objects (such as shape 3 can be described by $3 \times 3 + 1$), geared towards describing a general shape.

DISCUSSION AND CONCLUSIONS

Change in teaching practices towards explorative instruction has been a notoriously difficult process to capture (Heyd-Metzuyanim et al., 2018). In the present study, we offer first steps to applying the commognitive framework, with its precise definitions of ritual and explorative routines, to capture this process. The commognitive approach has been widely used in the study of processes of mathematics learning in interaction

(see review in Herbel-Eisenmann et al. 2017). Its usefulness for the study of teaching practices has only recently started to surface (Heyd-Metzuyanim et al., 2018; Nachlieli & Tabach, 2018). In the present study, we show this approach can illuminate the process often known as "lowering of cognitive demand" (Stein & Smith, 1998), as it happens in teacher-learner interactions. This has important advantages over approaches that simply show *that* such lowering occurs. Our study sheds light on *how* this process occurs. We saw the teacher, as a reaction to children not producing expected narratives, "broke-up" the expected narratives into meaningless parts. We also saw that this ritualization process could change through a process of professional development process. In the case of Simone, the change occurred very gradually and over a long period. It remains to be seen, in future studies and PD interventions whether awareness of such discursive patterns of ritualization can help teachers make the transition towards more explorative instruction faster and more efficiently.

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