A case study of a first-grade teacher's quality of implementation of mathematical tasks

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The aim of this study is to investigate a first-grade teacher’s quality of implementation of mathematical tasks regarding changes in the implementation within the scope of professional development (PD) program. The quality of implementation of mathematical tasks was analyzed through the instructional quality framework of Stein and Kaufman (2010) including maintaining cognitive demand, attending to students’ thinking and the intellectual authority in mathematical reasoning. This is a qualitative case study focusing on the teaching of a first-grade teacher with 40-year experience in teaching. 13 lessons were video-recorded and weekly meetings were audio-recorded. All data were transcribed for content analysis. The preliminary results indicated that there was a slight positive change in implementation quality of tasks throughout the PD program.

Keywords: Mathematical tasks, cognitive demand (CD) of a task, intellectual authority, student thinking, implementation quality.

Introduction

Mathematical tasks are the units of instruction in mathematics that create an environment for students to work mathematically. To explore mathematics instruction and potential changes in it, an investigation of teachers’ selection and implementation of mathematical tasks is necessary (Hsu, 2013). Stein et. al. (2000) characterized use of a mathematical task through four successive phases in Mathematical Task Framework (MTF); (1) task as appears in curricular materials, (2) task as set up in the classroom, (3) task as enacted in the classroom and (4) student learning. Teachers select or develop, present and implement mathematical tasks in their instructional processes.

Stein and Kaufman (2010) define the high-quality mathematics lesson through the maintenance of high-level cognitive demands (CDs), attending to student thinking and vesting intellectual authority in mathematical reasoning. The first is to maintain a high level CD through the steps of MTF. Doyle (1988) described a cognitive demand of a task as the cognitive processes necessary for successful completion of the task. If mathematical tasks require high CD level, these tasks need to foster students’ high level cognitive processes such as reasoning about the mathematics concepts involved, problem solving, making justifications, making sense of representations etc. Maintaining high CD of a task would require sustaining a focus on such processes through the steps of MTF.

Based on Doyle (1988)’s work, Stein et al. (2000) divide mathematical tasks into two categories as high level CD and low level CD. Each category consists of two subcategories. Memorization tasks and procedures without connection to mathematical concept tasks (P without C) belong to low levels CD. The procedures with a connection to mathematical concept tasks (P with C) and doing mathematics tasks are high levels CD (see Stein et. al., 2000 for a detailed explanation of these categories in Task Analysis Guide). Literature indicates that students show their best performance
on reasoning and problem solving when tasks are maintained in high level CD (Stein et. al., 2000). However, in most practices high level CD cannot be maintained and there is a decline in CD during set up and implementation of tasks (Tekkumru-Kisa & Stein, 2015).

Attending to students’ thinking is about paying attention to what students tell regarding mathematics (Stein & Kaufman, 2010). The goal is to gather students' strategies, representations, understandings or thinking, to make them heard and to use them in classroom discussion in order to construct conceptual understanding. Vesting intellectual authority in mathematical reasoning emphasizes that the authority in the classroom needs to be in mathematics itself, especially in mathematical reasoning. Therefore, teachers are not acting as the judge to tell whether student responses are right or wrong (Stein & Kaufman, 2010).

Approaches to mathematics teaching have been going through changes in many countries in the last two decades. The emphases on problem-solving and reasoning for conceptual understanding, i.e. reflections of high levels of CD, are prominent in many countries’ recently revised mathematics curricula and curricular materials. At times of change, teachers are the agents who enact curricular and pedagogical changes in the needs of students by arranging the learning environments and implementing the instruction. However, teachers have difficulties while adapting to new approaches in new curriculum (Davis, 2003). Especially while teachers are expected to implement tasks focusing on conceptual understanding, they continue to teach mathematics in a traditional way; focusing on practicing procedural skills (Hsu, 2013). In Turkey, there are similar changes in the curriculum, mathematical tasks in textbooks are aiming to reflect this focus (Ubuz et. al., 2010), and hence teachers’ implementation of mathematical tasks requires a close attention.

In many international studies, the whole process in MTF has been investigated considering the change in curricular approach (e.g. Charalambous, 2010; Stein & Kaufman, 2010). The studies mostly focus on how CD of a task maintained through the phases of MTF (e.g. Charalambous, 2010). In a Turkish context, the studies related to investigating teachers’ implementation of mathematical tasks are scarce (e.g. Ubuz & Sarpkaya, 2014). Especially there is no study found taking all three components of instructional quality into consideration.

Due to demands of a new curriculum on teachers, we implemented a professional development (PD) program in a private primary school in Turkey. We aimed to investigate how the quality of teachers' implementation of mathematical tasks progresses through the PD program. Therefore, current paper is a part of the project. The aim of this article is to examine a case of first-grade classroom teacher’s implementation quality of mathematical tasks throughout a year. The research question is:

1. How does a first-grade teacher's quality of implementation of mathematical tasks change during a professional development program?

**Method**

A qualitative case study approach was adopted, aiming for in-depth analysis of a particular situation or a complicated situation in a realistic context. Neşe (pseudonym) was a first-grade teacher at a small private primary school in İstanbul and was one of the participants who joined the PD
program. In her classroom, there were 16 students whose SES background varied from middle to high. We chose Neşe as the case because of her initial resistance to changes regarding implementation quality of mathematical tasks. At the beginning of the study, she claimed she already practiced in a way to foster high level cognitive processing. During times she claimed she could not follow the kind of teaching suggested by the implementation quality of tasks framework, she highlighted that her first graders required detailed teacher directions of what needed to be done, tasks focusing on singular skills or knowledge at a time. She wanted to spoon-feed them since the students needed experiencing success in tasks. Besides, she had approximately 40 years of experience in teaching as a classroom teacher and had deeply rooted classroom practices. She explicitly referred to this fact as a potential reason for her resistance to making changes in her practice. Neşe was a typical case of experienced teachers who have deep-rooted beliefs and are skeptical to new approaches (Ghaith & Yaghi, 1997).

Data collection
In the PD program, we adopted Borko’s (2004) phase 1 teacher professional development research approach through the collaboration of teacher and researchers in one school. We, as two mathematics education researchers, aimed to create a community of learners where researchers and teachers discuss their ideas together. Classroom observations were done approximately twice in every month. While observing the classrooms, we were nonparticipant observers who took field-notes and video-recorded the lesson. The video recordings were used for two purposes; (1) research data and (2) teacher learning. We had weekly meetings with teachers to discuss their implementation of mathematical tasks based on the videos. The teachers were watching their videos before the meetings and then reflecting on them. The meetings lasted for 40 minutes and were audio-recorded. Furthermore, mathematics lesson plans for the coming week were also discussed. We gave suggestions for teaching and planning lessons but made sure teachers made the final decisions. Besides, in order to explore MTF’s first step, before observation, we wanted teachers to send us their plans for the lessons to be observed. 13 lesson observations were done in Neşe’s classroom. 44 mathematical tasks were used in these lessons. However, not all tasks were present in the lesson plans she provided.

Data Analysis
For the quality of implementation of mathematical tasks, all videos were transcribed and coded based on Classroom Observation Coding Instrument (Stein & Kaufman, 2010). Based on the instrument, we coded intellectual authority in mathematical reasoning ranging from 0 to 2 and attending to students thinking ranging from 0 to 3. For the maintenance of CD, we used the paths provided by Charalambous (2010) (see Figure 1). For interrater reliability, two mathematics education researchers coded 4 of the 13 lessons including 11 of the 44 tasks independently. Cohen’s kappa was calculated to check agreement between raters for coding of CD of tasks, CD of task set-up, CD of task enactment, student thinking and intellectual authority. Cohen’s kappa values were κ =.784, κ=.694, κ =.792, κ =1.00, and κ = .792 respectively, which shows a high level of agreement between raters. Beyond the provision of descriptive statistics, we will present key episodes from her
teaching practice and comments in the meetings to document teacher resistance to change and teacher change in terms of her quality of implementation of tasks.

![Figure 1: Paths for the maintenance of CD (Charalambous, 2010, p.258)](image)

Results

Neşe used 44 tasks in total throughout 13 lessons. Sixteen of 44 tasks were not laid out explicitly in the lesson plans Neşe provided. Table 1 summarizes CDs of the tasks with respect to semesters. The table shows that about 61% of the tasks in the second semester were set up as cognitively demanding compared with only about 43% of the tasks in the first semester. In the first semester, about 57% of the tasks Neše presented required low cognitive processes (i.e. recalling information, applying algorithms). Table 1 also indicates similar trends in enactment phase; Neše implemented about 61% of the tasks at a high level in the semester 2 while she enacted about 33% of the tasks at this level in the semester 1. When the maintenance of CD was analyzed, it was seen that Neše mainly maintained CD at its intended level for all phases for both semesters. However, while Neše maintained about 59% of first semester’s tasks as low-level (Path B), she maintained about 73% of second semester’s tasks as high-level (Path A). For only two tasks throughout the whole year, she did not maintain cognitively challenging tasks; the decline occurred during enactment phase (Path C). The analyses show that Neše’s choice of tasks was determinative for the maintenance of CD.

<table>
<thead>
<tr>
<th>CD levels of tasks</th>
<th>Semester 1</th>
<th>Semester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planning</td>
<td>Set-up</td>
</tr>
<tr>
<td>Memorization</td>
<td>f</td>
<td>%</td>
</tr>
<tr>
<td>P without C</td>
<td>3</td>
<td>14.3</td>
</tr>
<tr>
<td>P with C</td>
<td>7</td>
<td>33.3</td>
</tr>
<tr>
<td>Doing math</td>
<td>6</td>
<td>28.6</td>
</tr>
<tr>
<td>Not present</td>
<td>1</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Table 1: Descriptive analysis of CD levels of tasks

Table 2 shows the limited work Neše did to uncover student thinking in the first semester (i.e. she mostly asked for short or one-word answers). She did not connect students’ responses in the discussion. However, there were slight differences in her use of tasks where she used students’ answers to direct and connect the discussion on 8.7% of the tasks in semester 2. She demanded
explanations from the students, called on certain students for directing the discussion to specific outcomes and connected the discussion for a fruitful experience for students as a classroom community.

<table>
<thead>
<tr>
<th>Categories for attending to student thinking</th>
<th>Semester 1</th>
<th>Semester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0) no attention to student thinking</td>
<td>f</td>
<td>%</td>
</tr>
<tr>
<td>(1) limited attention - some student explanation</td>
<td>6</td>
<td>28.6</td>
</tr>
<tr>
<td>(2) purposeful selection of responses, attention, but no connected discussion</td>
<td>11</td>
<td>52.4</td>
</tr>
<tr>
<td>(3) purposeful selection, attention and connected discussion</td>
<td>4</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Table 2: Descriptive analysis of attending to student thinking

Table 3 shows that the nature of Neşe’s practices on judging the correctness of students’ work was slightly different in the second semester. She was in charge of deciding what was correct or not for the most of the tasks in semester 1. Although she wanted students to prove or check the correctness via mathematical tools, she was the one confirming students’ answers at the end. In semester 2, she continued with similar practices; but she also experienced teaching episodes where mathematics was the judge students used to decide on the correctness.

<table>
<thead>
<tr>
<th>Categories for intellectual authority</th>
<th>Semester 1</th>
<th>Semester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0) judgments of correctness derived from teacher or text</td>
<td>11</td>
<td>52.4</td>
</tr>
<tr>
<td>(1) judgments of correctness sometimes derived from teacher or text, but also some appeals to mathematical reasoning</td>
<td>10</td>
<td>47.6</td>
</tr>
<tr>
<td>(2) judgments of correctness derived from mathematical reasoning</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3: Descriptive analysis of intellectual authority in mathematical reasoning

Illustrative episodes from Neşe’s lessons

In this part, we will present two episodes from Neşe’s implementation quality of tasks. The first episode illustrates Neşe’s common use of non-challenging, low level CD tasks throughout all phases of MTF. There were elements representing her resistance to changing her practice. The second episode presents how Neşe maintained a cognitively demanding task through letting her students struggle and encouraging their ideas to come out, practice emerging more prominently in the second semester. Neşe’s comments from meetings about the tasks in the episodes gave insight about the nature of change in her practice.

Making 10. This episode is from a lesson on pairs of numbers that make 10, covered at the beginning of the PD program. In the plan of the lesson, she stated the goal as discovering the pairs of numbers that make 10. The task in the episode included nine possible pairs that would make 10. The students needed to find one of the pairs to make 10. The task and the coding decisions for this episode are presented in Table 4. While implementing the tasks, Neşè directed students to count the flowers as seen in the sample item. In doing so, she made available the unknown to the students. Neşe eliminated opportunities for students to explore the pairs that make 10 by focusing on
counting procedure and finding the answer. This led students not to use high cognitive processes, or think about the operation they were engaged in; counting the flowers was enough for the completion of the task. Neşe had similar trends in her implementations of the first semester’s tasks.

<table>
<thead>
<tr>
<th>The Task</th>
<th>Coding Decisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many more needed to make 10?</td>
<td>The task was coded as procedures without connections for task selection, set-up, and enactment. Neşe expected students to count the flowers to decide what would be the unknown of the pair that makes 10. Since the focus was on counting the flowers, students enacted the task by not relating with pairs of 10, but counting the flowers and writing the unknown number. She did not attend student thinking; she asked for completion of the task. The judgments regarding correctness were derived from the teacher; she checked student’s work constantly.</td>
</tr>
<tr>
<td>Sample item:</td>
<td></td>
</tr>
<tr>
<td><img src="image.png" alt="Image" /></td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Making 10 task and coding decisions of the making 10 task

In the follow-up meeting of the lesson, Neşe did not prefer to comment on the episode before we made any comments. We pointed to the task’s low level CD and Neşe’s expectations from the students not being as high as targeted with the goals of the lesson. We emphasized the importance of giving opportunities for higher-level thinking and improving teaching towards this aim. After such comments from the researchers, Neşe wanted us to lower our expectations from her and emphasized her teaching habits by saying:

Neşe: If I bring open-ended tasks to the classroom, the students could not complete the task. I need to use such repetitive activities for students to learn. I have been using teacher-centered approach for years. Do not expect me to improve my teaching. At most, two years later I will be retired from teaching. Do not try hard for me. Contribute to younger teachers (personal communication, November 26, 2014)

Yet we emphasized that we believed that there would be changes if she wished to work on together. This extract shows that Neşe held on to her experiences in teaching and her expectations about student learning. Neşe was reluctant to PD program because she wanted to quit teaching in two years. This reaction is an evidence for her resistance to change her implementation of tasks.

Subtraction Problem. This episode is from a lesson on problem solving using subtraction, covered towards the end of the PD program. The task and coding decisions are presented in Table 5. During the episode, Neşe expected students to analyze the problem and to explain their thinking by modeling the problem and writing mathematical sentences. Therefore, she maintained the complexity of the task by pressing for meaningful explanations so that the students realized the unnecessary information by asking, “Why do you think it is unnecessary information?” “Can you explain in more detail?” “Why don’t I use money?” “Why is the result 11, not 14 or not 27?”

In the post-lesson meeting, Neşe examined her lesson in detail before the researchers made any comments. She referred to the maintenance of CD in her comments. She had certain concerns about the set-up phase of the task after watching her practice.
The Task
Examine the following problem situation by modeling it. Write mathematical sentences and solve it. Explain your reasoning.

**There are 6 roses in our vase. Dad brought 8 tulips too. Mom said dad spent 10 ₺ for the tulips. Next day, mom realized 3 flowers faded. How many flowers are left in the vase?**

Table 5: Subtraction problem task and its coding decisions

She stated that the task was too abstract and so hard for the students. Then she pointed to getting students to struggle in order to construct meaning through abstraction as a necessary practice for learning:

Neşe: It would not be easy for students, but it is good to present the task abstractly. It is challenging for them and for me too. I think I maintained high-level CD. I did not just expect them to apply the subtraction procedure. I wanted them to question the problem situation, unnecessary information within the problem. I wanted them to explain their thinking by using manipulatives. It took too much time, but it was necessary for students to experience high-level cognitive processes. (personal communication, May 6, 2015).

Here Neşe showed the importance of supporting students’ reasoning in her teaching practice. The focus on explanations and justifications helped the teacher to implement the task with high quality. The post-lesson interview provided evidence for teacher’s change in her emerging practice and comments during the PD program.

Discussion & conclusion

This study aimed to investigate the changes in a first-grade teacher’s implementation quality of mathematical tasks during PD program. Neşe, our case, was one of the experienced teachers having difficulties with adapting educational innovations into their practices as illustrated in the literature (Ghaith & Yaghi, 1997). The PD program aimed to meet the needs of new approaches to mathematics education. The results indicated a slight positive difference in Neşe’s practices between first semester and second semester based on maintenance of CD, attending to student thinking and intellectual authority. The teaching episodes showed that the PD program contributed to the teacher’s approach towards implementing high quality of tasks that focus on problem-solving, reasoning and conceptual understanding (Stein & Kaufman, 2010). Neşe was resistant to change at the beginning of the PD program; her selection and implementation of tasks were low level CD in general (e.g. the making 10 task). However, high expectations from the researchers and the post-lesson interviews persistently focusing on the quality of implementation of tasks contributed to
emerging changes in Neşe’s teaching practice as well as the nature of her comments (e.g. the subtraction problem task).

This study contributes to the existing body of literature on change of teachers’ practices about the implementation of mathematical tasks within the context of a PD program. Especially in Turkey, there are a limited number of studies related to the classroom practices of primary school teachers in a climate of change of curricular approaches (e.g. Ubuz & Sarpkaya, 2014). Results of this study provide information about mechanisms of change in context and contribute to the development of larger scale PD programs.

Additional information

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