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Tasks analysis as a mean to reflect and (re)think the pedagogical practice of teachers who teach mathematics

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This study discusses how the analysis of mathematical tasks, within a teachers' in-service education study group, can help teachers who teach mathematics in the early years of Elementary School to reflect and (re)think their pedagogical practice. This research was carried out in a Brazilian public school, with the participation of 14 teachers. Within the in-service study group, the recognized importance of the tasks and their classification according to levels of cognitive demand by the teachers is discussed. The reflections and discussions in this study group allowed the identification of some changes in the teachers' perspectives in regard to tasks choice/preparation, the role of the teacher in the classroom and the recognition of students' capacities.

Keywords: Mathematical tasks, levels of cognitive demand, teacher education.

INTRODUCTION

The tasks proposed to students influence what and how they learn (Doyle, 1983; Stein, Smith, Henningsen, & Silver, 2009); therefore, it is essential for teachers to be prepared to select, in an informed way, the tasks to be proposed to their students and to support them in their work without reducing their complexity.

Several researchers have developed studies in which tasks are the focus of investigation, indicating that there is a relationship between the type of the proposed tasks and type of thinking developed by students (Doyle, 1983; Christiansen & Walter, 1986; Shimizu, Kaur, Huang, & Clark, 2010; Stein & Smith, 1998; Stein, Smith, Henningsen, & Silver, 2009). Thus, it is important to provide teachers with professional development opportunities to help them reflect on

the role and relevance of the task for the teaching and learning processes and make them realize that not only tasks play a significant role in these processes but also that the way they are explored by the teacher in the classroom is fundamental.

In this article, we present the results of a research whose objective was to investigate how tasks analysis in a context of in-service education can help teachers who teach mathematics in the early years of Elementary School to reflect and (re)think their pedagogical practice and, more specifically, to understand these teachers' perspectives in regard to the tasks' choice and preparation, proposition and implementation, based on the levels of cognitive demand of each task (Stein, Smith, Henningsen, & Silver, 2009).

THE IMPORTANCE OF TASKS AND THE LEVELS OF COGNITIVE DEMAND

Tasks are used by teachers for different teaching purposes and they may appear in different moments of the lesson as exercises and problems, for instance. In this study, task is viewed as a proposition made by the teacher in the classroom with the objective to focus the student's attention in a determined mathematical idea which implies an activity from his part (Stein, Smith, Henningsen, & Silver, 2009).

When planning their lessons, many teachers are not used to think about the reasons behind their task choices and many times this action is supported merely by the mathematics contents which they are working or those included in the textbook. According to Pepin and Haggarty (2007), tasks can and must be seen as "[...] a process that can potentially help to enhance mathematical understanding rather than simply a

vehicle for content” (p. 13). Next, three significant arguments related to the role of the task are presented to help teachers understand the importance of having a set of task selection criteria.

Firstly, “tasks with which students engage constitute, to a great extent, the domain of students’ opportunities to learn mathematics” (Stein, Smith, Henningsen, & Silver, 2009, p. 131). The student’s work is defined by tasks carried out by him/her, daily; however, some have the potential to mobilize complex forms of thought while others do not. Therefore,

tasks that ask students to perform a memorized procedure in a routine manner lead to one type of opportunity for student thinking; tasks that require students to think conceptually and that stimulate students to make connections lead to a different set of opportunities for students thinking (Stein & Smith, 1998, p. 68).

A second argument is that tasks are instruments used to connect the students’ learning objectives (Stein, Smith, Henningsen, & Silver, 2009). When choosing or preparing a task, it is important for the teacher to have a clear objective to propose to students. To think about the tasks’ objectives prior to implement them can help teachers create a classroom environment that motivates the student to get involved in the solving of the proposed tasks.

A third argument is that tasks affect significantly the reasoning process students develop in order to solve them (Stein & Smith, 1998). Therefore, teachers should prioritize cognitively challenging tasks with the potential to engage students in complex thinking forms. This type of task can help students develop reasoning forms and strategies that allow them to go beyond the memorization of facts and procedures. However, the teacher must be aware of the fact that to select or prepare this type of task does not guarantee students’ engagement since there are several classroom factors that can contribute to the maintenance or decline of the task’s cognitive demand (Stein, Smith, Henningsen, & Silver, 2009).

Tasks can be analyzed from several perspectives such as nature, characteristics, number of strategies used to solve them, levels of cognitive demand among others. In this study, tasks are analyzed based on their levels of cognitive demand since, according to Stein,

Smith, Henningsen and Silver (2009) “the cognitive demands of mathematical instructional tasks are related to the level and kind of student learning” (p. 17).

For Stein and Smith (1998), tasks can be grouped in four levels of cognitive demand: memorization; procedures without connections; procedures with connections, and doing mathematics. The first two categories involve tasks with lower-level of cognitive demand and the last two refer to high-level of cognitive demand tasks. With the purpose to provide support to teachers during task analysis according to their levels of cognitive demands, in a context of teachers continuing education, these researchers prepared a Guide to Tasks Analysis (Appendix 1), which includes a list of tasks characteristics in each one of the four levels of cognitive demand that can be used as a parameter for their classification.

The teacher can still use this guide “as lens for reflecting on their own instruction and as a shared language for discussing instruction with their colleagues” (Stein, Smith, Henningsen, & Silver, 2009, p. 2). Thus, by selecting/preparing tasks based on their cognitive demand allows the teacher to look into what the students learn and how they work with the tasks; their actions at the moment of proposing and implementing the tasks; the factors that affect the proposition and implementation of the tasks, which may contribute to their maintenance or decline.

However, in order to choose or prepare tasks based on the levels of cognitive demand, the teacher must not only be informed by some principles for tasks analysis but also know their students deeply and pay attention to aspects such as age, learning pace, level of education, mathematical knowledge and prior experiences so that those tasks constitute a real challenge for students (Stein, Smith, Henningsen, & Silver, 2009).

RESEARCH CONTEXT AND METHODOLOGICAL PROCEDURES

This research was developed within an in-service education program, in a study group context, with the participation of 14 teachers working with the early years of a public Elementary School in Brazil. The teachers had more than eight years of experience and played different functions in their schools.

The study group was coordinated by two researchers, one of them is the first author of this article, from the Mathematics Education and Sciences Teaching Graduate Program– PECEM¹, and was part of an in-service education project outlined by the school within the City Education Department annual planning. One of the goals of this study group was to motivate participants to learn about the levels of cognitive demand of the tasks and how to analyze tasks based on some principles. The study group met weekly, for one hour, for a period of six months and it focused on tasks analysis based on the categories proposed by Stein and Smith (1998).

The group discussions were organized in four phases. In the first, we discussed the tasks brought by the teachers and, they presented and explained the reasons that guided the selection of these tasks and how they worked with the tasks in the classroom. In the second, the teachers studied and discussed the features of tasks in each level of cognitive demand and later they conducted a new analysis of these tasks, classifying them according to the level of cognitive demand. In a third moment, the teachers worked on tasks with different levels of demand cognitive proposed by the coordinator of the study group, they analyzed and classified these new tasks and some teachers have

expressed interest to apply them in the classroom (due to space limitations, it is not possible present the tasks in this paper). After this implementation, in the fourth phase, the study group discussed the relevant points and the difficulties faced by the teachers in the classroom, as well as evaluated the importance of task analysis and cognitive demand levels.

The instruments adopted for data collection included transcriptions of the audio recordings of the meetings so that the participants’ speeches could be registered in their original form, keeping the integrity of the dialogues; written productions, with comments and reflections of teachers on discussions that occurred in group (free writing) and semi-structured interviews with some teachers. To identify the instrument from which the information was obtained, we use the fictitious name of the participant followed by the first letter of the instrument. So, the letter G was used for group meeting followed by the number of meeting, P for written productions, and I for interviews. For example, the identification of an information given by Cintia in the first meeting, is registered as “(Cintia, G1)”. Due to space limitations, in general, only one excerpt was presented as an example of each analysis unit. Analysis units were constructed after several readings of the meetings’ transcriptions, written productions and interviews, highlighting relevant excerpts for our study. Data analysis uses the Tasks Analysis Guide as reference (Stein & Smith, 1998).

¹ This program is being developed at State University of Londrina, Brazil.

Reasons given by the teachers for their choice of tasks	Tasks allow teachers to approach mathematical content	I choose a task to work with content. If I want to work with the operations, the multiplication table, I choose tasks that allow me to work with them. If the content is measures, for instance, I choose a task that explores this content (Isadora, G1)
	Tasks allow to verify whether the mathematical content was “assimilated”.	When I propose tasks to my students it is always with the intent to check whether they have learned the content and also to verify which contents still need more work to be done [...] (Fabiane, P1)
	Tasks allow to work with non- mathematical aspects	I never choose a task which deals exclusively with Mathematics. I choose a problem that involves several areas such as Sciences, Portuguese, Geography, several disciplines, a task that does not involve only calculations. (Carla, G1)
	Tasks allow to relate mathematics with the student’s reality	[...] Tasks must always be connected with the child’s reality. Children learn mathematics for their life. [...] They are more motivated (it’s more pleasurable) when they have to solve real problems. (Mariana, G1)
	Tasks allow to develop reasoning skills	The objective of the tasks must be to contribute with the development of the student’s reasoning skills. (Cintia, P1)

Table 1: Summary of the initial reasons given by teachers for their tasks choices

Reasons given by the teachers for choosing tasks

One of the actions developed in the beginning of the study group was a discussion over the tasks teachers had brought upon request of the teacher educators. They were asked to explain the reasons behind their tasks choices which included: to approach mathematical content; to verify whether the mathematical content was assimilated; to work with non-mathematical aspects; relate mathematics to the student’s reality and to develop reasoning (Table 1). Some teachers gave more than one reason for their choices of the tasks.

The reasons presented by the teachers show that most of the tasks they selected are based on memorization or on procedures without connections (Stein, Smith, Henningsen, & Silver, 2009), i.e., they require only the reproduction and memorization of contents, rules and formulas learned previously, without establishing connection with concepts or meanings that give support to the contents given, and being more focused on correct answers than on the student’s understanding.

Tasks analysis and the levels of cognitive demand relevance

The study of the levels of cognitive demand, the reflection on the tasks’ role in the teaching and learning processes and of the high-level of cognitive demand tasks led teachers to think about their initial reasons to choose tasks and develop another view in relation their selection or preparation. Next, we present a table with some points provided by the teachers on the relevance of tasks and levels of cognitive demand (Table 2) during the study group work.

Teachers started to notice that tasks have different characteristics and that this difference can be interpreted through their levels of cognitive demand, bringing implications to the student’s activity and to the complexity of the mathematical processes involved. They also became aware that their tasks selection criteria were focused almost exclusively on the coverage or verification of mathematical content.

Signs of changes triggered by discussions, reflections and task analysis

The actions developed by the study group on the reasons for choosing tasks, levels of cognitive demand as a tool to classify them and on tasks analysis allowed us to identify signs of changes in regard to tasks choice, role of the teacher in the classroom and student’s capacity (Table 3).

During our first meeting, teachers had difficulty in justifying their choices to the group, considering that the habit of thinking about *why the tasks were selected; for they serve; what contents they cover, their level of complexity and whether the objectives were met*, it was not common practice of most teachers who participated in the study group. *“I never stopped to think why I chose the tasks. Today I become to realize how important it is to think about it”.* (Ana Livia, G1). *“Great! You know, when I gave the task to my students I did not think about the objective, about the reason behind it; so, I’ll pay more attention to it from now on”*(Ana Júlia, G1).

During the group sessions, some teachers started to become more aware of the importance of selecting tasks and aggregating levels of cognitive demand to their criteria, reducing the number of tasks proposi-

Reflections on tasks analysis and levels of cognitive demand	Tasks relevance for the teaching and learning processes	I had never stopped to think about the importance of tasks for the student’s learning process; but, now, here with this group, with these discussions and being aware of the difficulties some teachers had to justify their choices I realized how important it is to reflect on it. I realized that we have chosen tasks haphazardly. (Vitória, P1)
	The relevance of learning about the levels of cognitive demand of the tasks	[...] knowing about levels of cognitive demand changed my way of thinking and choosing tasks and helped me think better about how and which task to use and whether it is going to be useful to the public at hand [...]. (Ana Júlia, I)
	The relevance of high-level of cognitive demand tasks	It is extremely important to work with high-level of cognitive demand tasks, since they promote the development of autonomy, self-confidence and critical thinking, argumentation and therefore to think mathematically and to search for solutions to problems. (Denise, P19)

Table 2: Reflections on tasks and levels of cognitive demand

Change signs	Sentences that show the signs of change
Tasks selection by the teacher	<p>These reflections have contributed a lot to my mathematical tasks selection criteria and also to tasks from other subjects. We are becoming more careful, thinking not only on the objectives of the tasks but also on their levels of complexity and the students, trying to imagine how they will react to the task and which are their possible answers. (Cintia, P6)</p> <p>The reasons I had before remain, but now I also select high level tasks which involve reasoning and not only formulas. But, I look for a balance among the tasks. Students still have lots of difficulty, so it is impossible to work only with high level tasks, that's why I stick to my old set of criteria (Fernanda, I)</p> <p>Today I look for tasks that make my students think; not only tasks that focus on the correct answer but on how the student will carry it out, on the process. But, I continue choosing tasks for verification, which are also important (...) I think that the other criteria came up due to my participation in the study group otherwise I would not have learned about them and become aware of their existence (Ana Júlia, I).</p>
The role of the teacher	<p>My posture in the classroom has also changed. Now I try to question the student more to know about his reasoning process (Ana Júlia, G17)</p> <p>[...] This group work not only helped us know the task but also to try to work with tasks in a different way. For example, I never gave the opportunity for my student to explain their work. Now, I always ask them to explain their work process to me and their classmates. (Fabiane, G17)</p>
The students' capacity	<p>I learned to value my students and their capabilities. Before I saw them as individuals coming from a poor neighborhood, with whom I was supposed to teach some mechanical skills and I would be very happy if they were able to learn them. However, I learned that they can achieve more; I did not know their potentials so, when I gave them the task you suggested I saw how wrong I was and that I could go beyond mere mechanical tasks. (Mariana, I)</p> <p>I was surprised by some students who many times have difficulty in carrying out simple mathematical operations, an algorithm; however, they solved very fast the sequence's problem they did very fast without questioning [me] much. Other students, who were always the first to finish a routine task, had difficulty solving this problem. (Denise, G13)</p>

Table 3: Sentences that show signs of change by the teachers

tions focused on memorization or on the realization of a procedure without connections.

In regards to their role, discussions and tasks analysis allowed teachers to understand the impact of their actions on some teaching and learning processes, especially in relation to tasks choice and to promote a change in the way to implement tasks in the classroom. This way, they started to promote teaching and learning processes focused on the students' understanding.

As for the student's capacity, tasks implementation and solution helped teachers to realize that, many times, they underestimate the cognitive capacity of their students, their specific learning pace and difficulties and that the role of the teacher is to help them think on how to solve the task without removing its challenges (National of Council of Teachers of Mathematics, 2000).

FINAL CONSIDERATIONS

To think about the tasks they propose was not a usual practice for most teachers in the study group. Consequently, in the phase of the study group, some of them had difficulty justifying their choice of the tasks to be used in the classroom. However, despite these difficulties, some teachers were able to voice their reasons for choosing the tasks such as to use a task to approach mathematical content or verify whether the mathematical content was assimilated, and these practices are strongly present in the pedagogical practice of these teachers.

To learn about the levels of cognitive demand and analyze tasks was highly significant for most teachers, since they were able to realize the importance of thinking about the tasks and the way to work with them in the classroom. Thus familiarity with the lev-

els of cognitive demand has also helped teachers to understand that tasks with a high-level of cognitive demand have the potential to involve the student in a work focused on reasoning and on understanding, making them choose and propose this kind of tasks.

Teachers became more critical regarding their choices of tasks which became an action based on a lot of thinking. They become more attentive to the objectives of the task, trying to anticipate how students would react to it and their possible solutions.

In addition, the teachers had the opportunity to reflect on their role in the classroom, since they realized that their attitudes and decisions influence their students' learning. Therefore, some teachers considered that they changed the way they teach by questioning more the students during the lessons, to know about their line of thought rather than being only concerned with the correct answers and mainly giving them more opportunities to justify their reasoning processes. Consequently, this change in the teacher's attitude shed a new light on the way they regard the students, since some of them used to underestimate their students' capabilities.

Thus, according to Stein, Smith, Henningsen and Silver (2009), to know about the levels of cognitive demand allowed teachers to differentiate mathematical tasks in order to identify those that offer opportunities for students to think without being led by their superficial characteristics.

However, even acknowledging the potential of tasks with high-level of cognitive demand, teachers have only aggregated them to their previous reasons. The lack of confidence in dealing with these tasks, the fear of not being able to meet the objectives of the lesson and at the same time demotivate students due to their difficulties and the justification that memorization and verification tasks are also relevant, are some of the arguments presented by teachers to justify the low frequency of high-level of cognitive demand tasks in their work. Such resistance must be understood within the context of an instituted professional practice, considering that the knowledge of levels of cognitive demand can help teachers to reflect on their teaching style and focus more on what students learn and how they work on a task as well as on their actions and attitudes when proposing and implementing a task.

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APPENDIX 1. GUIDE TO TASKS ANALYSIS (STEIN & SMITH 1998)

Tasks Characteristics that involve low-level of cognitive demand	Memorization	Procedures without connections
	<ul style="list-style-type: none"> - Involve either the reproduction of facts, rules, formulas learned previously or memorization; - They cannot be solved by using procedures because they are either not necessary or the time is short to use them; - They are not ambiguous and involve the exact reproduction of the subject studied previously and what is to be reproduced is clear and directly stated; - No connection with concepts or meanings underlying the facts, rules, formulas or definitions taught or reproduced. 	<ul style="list-style-type: none"> - They are algorithms. The use of one procedure or is specifically indicated or evident due to a previous instruction, experience or question location; - Require limited cognitive demand to resolve it successfully. There is little ambiguity on what needs to be done and how to do it; - There is no connection with concepts or meanings underlying procedures used initially; - They are focused on the production of correct answers instead of on the development of Math comprehension; - Do not demand explanations or whenever needed, they are explanations focused only on the description of the procedure used.
Tasks Characteristics that involve high-level of cognitive demand	Procedures with connections	Doing Math
	<ul style="list-style-type: none"> - Focus the students' attention on the use of procedures to develop an in-depth knowledge of concepts comprehension levels and Math ideas; - Suggest ways to be followed (explicitly or implicitly), which are general, common procedures which have intimate connection with conceptual ideas; - Usually represented by several ways (such as diagrams, manipulatives, symbols and problem-situations). They make connections among multiple representations that help develop meanings; - Demand some degree of cognitive effort. Although general procedures can be followed, they cannot be followed without being fully understood. Students need to get involved with the conceptual ideas underlying the procedures to be followed in order to fulfill the task successfully and develop comprehension. 	<ul style="list-style-type: none"> - Demand complex thinking skills rather than algorithmic skills, and the tasks do not suggest, explicitly, a predictable way to be followed, instructions for its solution, or an example, which, when well-trained, could lead to their resolution; - Demand that students explore and understand the nature of Math concepts, procedures or relations; - Demand high monitoring or high regulation of the student's own cognitive process; - Require students to mobilize relevant knowledge and experiences make appropriate use of them during the task; - Require students to analyze and examine the task actively and whether it has limited resolutions and solutions limitations; - Demand considerable cognitive effort and may involve some levels of anxiety from the students' part for not having a previous natural list of the processes demanded by the problem.