Mathematical conversations with Dja

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Introduction

The problem

Throughout the 80's I taught mathematics in Portugal, Angola, and Cape Verde[1]. In all the places I taught, in spite of large contextual differences and cultural backgrounds, similar behavioural patterns toward mathematical tasks emerged: there were always the students who could deal with almost any mathematical task, the students who sometimes were capable of doing the tasks, and the students who had great difficulties with mathematical tasks.

Among the group of "medium-ability" students, the way that each student synchronized with the mathematical task or, the way that he/she almost immediately decided to give it up was surprising, mostly because the mathematical problem which was being rejected did not have a different model from one handled well previously. The mathematical content involved usually remained the same, and the language used in the problem's enunciation was also comparable. These observations led to my interest in knowing not only why this middle group of students decided to give up performing their roles as mathematical problem-solvers, but also why such a practice is so common.

Thus, my aim is to uncover how the student attempts to solve the problem and to attempt to understand what leads the student to stop seeking a solution to the problem. My focus will be on the student's direct interaction with the text of the mathematical problem.

The method

Due to the idiosyncratic nature of the phenomenon that I intend to analyse (that is, the problem that provokes lack of performance in one student may not provoke it in another), and the random way in which it manifests itself (that is, the lack of an intelligible reason for predicting failure, since the problem is similar, regarding mathematical content, and linguistic format, to the previous one handled well), it demands an individualized approach that will look at the problem from the student's point of view, to see what leads to a failure on the part of the student to continue attempting to solve the problem.

Furthermore, in order to study the conditions which make it possible to reject a mathematical task or problem, I cannot isolate myself from the performance, because as an observer of the "spectacle" I can only describe and decode it. Rather, I need to experience the performance and its dynamics, and get as close as possible to the performer. I have to interact with him or her, namely to slow down the decision in order to bring into speech the realities that were colliding with the role of the mathematical performer. In other words, I am interested in the "speaking subject as a means of action and expression" (Bourdieu, 1977, p. 1).

The literature

Rotman's semiotic model of mathematics. Rotman's semiotic model of mathematics (1993) presents a theoretical framework to examine the doing of present-day mathematics. This model was conceptualized with mathematicians in mind, and is developed through an elaborated analysis, wherein the features of mathematical discourse are essential.

In the semiotic model of mathematics, mathematical activity is viewed as "carrying out thought experiments"[2] (Rotman, 1993, p. 67), and mathematical reasoning is perceived as the acting out of different sequential steps required in order to accomplish a "thought experiment".

This semiotic model of mathematics discerns three different figures or agencies — the Person, the Subject, and the Agent — that jointly process any mathematical activity. To better introduce each of the semiotic agencies, as well as to explain their different functions, it is necessary to consider at first the major discursive features of mathematics.

According to Rotman, mathematicians have two distinctive dimensions of discourse: the formal mode, or Code, and the informal mode, or metaCode. The formal discursive mode of mathematics is related to the objective and rigorous aspects of mathematics. It is what one finds in mathematical written texts, and it consists of the symbolic notation used in mathematical texts as well as its precise rules. The utterances made in natural language which are mixed in the symbolic notation are also a part of the Code. As Rotman says,

> I shall call the sum total of all these resources — that is, the unified system of all such rules, conventions, protocols, and associated linguistic devices which sanction what is to be understood as a correct or acceptable use of signs by the mathematical community — the Code (1993, p. 69).

The informal discursive mode, or metaCode, concerns the different ways whereby the Code is contextualized and linked to historical, empirical, social, psychological, or cultural realities. In Rotman's words (1993) it consists of

> the mass of signifying and communicational activities that in practice accompany the first mode of presenting mathematics: drawing illustrative figures and diagrams; giving motivations: supplying cognate ideas; rendering intuitions; guiding principles, and underlying stories; suggesting applications; fixing the intending interpretations of formal and notational systems; making extra-mathematical connections (pp. 69-70).

Although the construction of mathematics embraces these two discursive dimensions[3], the metaCode is traditionally viewed as unrigorous and epiphenomenal when compared to the Code. Consequently, what is established by the Code (mathematical definitions, procedures, enunciations, problems, and demonstrations, as well as its discursive means) is what is promoted as mathematics, and considered as the "true" corpus of mathematical knowledge.

The main features of the formal discursive mode, as Rotman (1993) pointed out, are:

> First, every text written in the Code is riddled with imperatives, with commands and exhortations such as "multiply items in w", "integrate x", "prove y", "enumerate z", detailing precise procedures and operations that are to be carried out. Second, the Code is completely without indexical expressions, those fundamental and universal elements whereby such terms as "I", "you", "here", "there", "this", as well as tensed verbs, tie the meaning of messages to the physical context of their utterances (p. 7).

In considering the inter-subjective nature of mathematics, that is, that mathematics is done by humans to humans, Rotman examines the "recipients" of mathematical discourse, and sets up the three semiotic agencies. I will briefly summarize the semiotic model of mathematics.

Due to the discursive nature of mathematical texts, mainly the way these texts are written without temporal, spatial, or personal references, not only do they serve to convey the idea of mathematics as an atemporal and unpersonnal field of knowledge, but also they presume the existence of an "idealized subject", a transcultural disembodied person, who no matter his or her location, will read and interpret such texts according to previously defined, and consequently already "shared", conventions of the Code. In addition, all the imperatives, commands, and exhortations that saturate mathematical texts written in the formal discursive mode demand the performance of mathematical operations that are only executable through the manipulation of signs. These signs, as well as rules how to operate with them, are also an object of the Code's orienting descriptions, and call upon the presence of a "sign-manipulator" that will enact the actions in these "mathematical worlds". Hence, in order to satisfy mathematical texts' requests, in addition to the "idealized subject" that will mathematically make sense of them, the performance of a "sign-manipulator" is also demanded.

The three semiotic agencies arise as follows:

The *Person* — that operates within the metaCode, and consequently is embedded in psycho-social, and historic-cultural references. The Person has access to dreams, motivations, narratives, and speaks with the personal pronoun of natural language.

The *Subject* — is an idealized person that is addressed by the Code and functions within it. The subject cognitively interpret signs, and mathematical texts, according to the rules and conventions of the Code.

The *Agent* — a machine, that mechanically manipulates the signs of the Code, without concerns of meaning and interpretations.

As Rotman points out, the Subject is the most "visible and palpable" (1993, p. 81) of the three semiotic agencies. It is the Subject that is addressed by mathematical texts. However, the Subject's activity is expropriated from the excluded yet proximal presence of the Person, and it impels the Agent to produce.

The processes that accomplish the changes from the Person to the Subject correspond to the obscureness of reference and corporeality, and the processes that accompany the metamorphoses whereby the Subject gives rise to the Agent mainly coincide with the vanishing of "meaning and sense" (Rotman, 1993, p. 92).[4]

As Rotman (1993) argues, mathematical activity demands the simultaneous presence of the three semiotic agencies; only the Person can set up and/or respond to the thought experiment; only in the discursive dimension of the metaCode can mathematicians interpret the wholeness of a mathematical proof that is not contained in each one of its logical steps; and only the Person is allowed to search for the "idea behind the proof"[5] that gave rise to such a proof (Rotman, 1993, p. 80). Ultimately this means that the metaCode is the place where debate and eventually creation of the Code takes place. Furthermore, what Rotman (1993) also points out is that only through the discursive dimension of the metaCode that mathematical objects can acquire their own "status", in the sense that, only when historic-cultural processes are applied to mathematical objects do they get their meanings, and become endowed with their properties (Rotman, 1993, p. 82).

Classroom mathematical discourse. The features of the formal discourse of mathematics by and large inspire classroom mathematics discourse.

For example, according to Pimm (1987), mathematics classroom discourse's prevalent characteristics include the "widespread use of specialist terms such as quadrilateral, hypotenuse, and multiplicand" (p. 78). The passive mood and the imperative form are the major grammatical structures around which the discourse is organized. For example "consider", "suppose", "define", or "let x be the number" are the most common kind of expressions in mathematics classes (pp. 71-72).

In regard to the interaction between students and teacher, it is mainly based in the posing of "closed" questions (throughout the "sequence initiation (I)- response (R)- feedback (F)" (Pimm, 1987, p. 27)). Such an interaction fosters control of language production, not only in regard to the pattern of language used, but also in regard to the renewal of language. Moreover, by transcribing classroom mathematical conversations, Pimm found out that indefinite words such as "it" and "thing" were frequently used as a form of reference to mathematical objects.

Another classroom discourse particularity is the use of the pronoun "we". As Pimm (1987) remarked, the circumstances that surrounded the use of the pronoun "we" in mathematics classes are linked not only with "questions of power and dependence" (p. 68), but also with the " fear in mathematics of involving, and hence exposing, the self" (p. 70). In regard to the former circumstances, it is common among mathematics classes to couple imperatives with the pronoun "we", in this way forming expressions such as "Let us consider", or "Let us suppose", instead of simply saying "Consider" or "Suppose".[6] In this occurrence, although the pronoun "we" emerged as a means of "softening"[7] the imperatives, the speaker's intention is to focus upon the hearer the idea of a "uniform mathematical practice" (Pimm, 1987, pp. 68-70). In regard to the later circumstance, Pimm argues that the representation of mathematics as "something objective, absolute, permanent and impersonal (1987, p. 70) leads to the avoidance of the use of the pronoun "I", and its consequent substitution by the pronoun "we" "as a clue to generality" (1987, p. 71). Thus, imperatives and commands, as well as refraining of indexality, were also pointed out as common features of classroom mathematics discourse.

The case study

Dja is a 14 year old Capeverdian girl, who due to her father's profession, came into the USA in April 1991, with both her parents and three younger siblings. Coming from a middle-class educated family, when she left Cape Verde to come to the USA, she was in 6th grade of a public school in Praia, the main town of Cape Verde. She used to be a good student in mathematics, but, in the academic year of 92/93 she became concerned about her mathematical achievement and I started to try to help her with mathematics.

From then on Dja brought her mathematical materials, and weekly we looked over her notes, and the tasks assigned by the teacher in classes. She used to tell me what she was studying and liked, and what was difficult to her.

To the extent that we were proceeding with our conversations, and exchanging viewpoints about mathematical topics and assignments, I became aware of Dja's mathematical knowledge. Dja's notes were mostly composed of large computations; calculus of numerical expressions with fractions, decimals, and percentages. From a computational viewpoint, Dja knew fractions, percentages, and decimals. Moreover, when I asked her to calculate in front of me these kind of expressions, she confirmed that she dealt with them adequately.

As I have mentioned before it was the "unconscious" facet of the way that "medium-ability" students almost immediately decide to give up from a mathematical task that I was looking for as a way to understand Dja's lack of mathematical performance. Thus, I was searching for a different kind of interaction between Dja and myself. I was interested in the discourse of the mathematical performer in these moments. I wanted to know what Dja thinks about when she thinks that she does not know how to solve a mathematical problem. I considered that it would be better to try to enhance her discourse about the problems, also trying, nevertheless, to ensure that Dja would be the one responsible for both initiating the dialogue and directing it. That way she probably would display what the problem invoked in her mind, and consequently would tell me what was not making sense in her vision of the task.

I was not mainly interested in the mathematical solution of the problem, (at least before attempting to understand what was leading Dja to lack of mathematical performance). The mathematical materials that I was looking for should be basic and simple, that is, they should require few steps, and small calculations for their solution, and in addition they should be compatible with Dja's mathematical knowledge.

As we became accustomed of doing, Dja read the tasks, completed them, and afterwards would explain to me what she had done. Or, as was also our practice, after reading Dja would tell both what were the questions posed by the tasks and the necessary information to answer them, and finally identify the mathematical tools required for the solution. Another alternative was to ask Dja to think about a task at home, and then tell me about it later. These practices seemed to work for my purposes, because it

In this way, Dja did several mathematical assignments without mathematical obstacles. Despite Dja's success, in the middle of our encounters some mathematical problems appeared that provoked Dja's giving up from her mathematical performance. For Dja, these moments were failures, and she tried to resign herself to her lack of giftdness in mathematics, her justification being rationalized on the basis that the assignments were too complex for her knowledge, and that she was not capable of knowing enough mathematics.[8] For me, these moments were felt as challenges to my capacity of teaching. I was waiting for these moments, but I also feared them; I was afraid of not being able to elicit from Dja what she thought in these moments.

The problematic mathematical situations that I afterwards present were, thus, singular during our mathematical encounters. At first they were just situations that we were trying to work out, but unlooked for, they liberated unexpected contexts which triggered new problems, emotions, and situations to think about. In the following situations Dja began by expressing that she was unable to solve in the proposed mathematical assignment.

Dja's view of herself as a mathematical performer

> "I mix up mathematics with other things,(...) that have nothing to do with it."

The following problem was posed to Dja.

Problem 1
A plumber's charge of $90 for a service call includes the cost of the first hour of work. For each additional hour or part of an hour, the charge is $45. What is the total charge for two

service calls, one lasting 3 hours 15 minutes and the other lasting 4 1/2 hours? (Benson, Dodge, Dodge, Hamberg, Milauskas, and Rukin, 1992, p. 15).

After a few moments, Dja told me that she did not know how to solve the problem to which I replied, "why?" After a few seconds of silence she asked me about the meaning of "plumber". But when I said that I was not sure, Dja revealed me that i was not important, that she had already understood that it was some kind of service She read the problem again and invited me to translate the second sentence of the tex "For each additional hour or part of an hour, the charge is $45", which I did. Then she invited me to translate the first sentence of the text "A plumber's charge of $90 for a service call includes the cost of the first hour of work", to which I replied tha it would be better if she herself translated all the problems's text[9]. However, before translating the problem's text she noted that,

> they did not pay the same amount of money in each hour,

and afterwards posed the question of what kind of jobs were like that.

We talked for a while about some professions, both in the US and Cape Verde, that eventually would use a similar process of payment, as for example the ones which required the displacement of large machines, and finally Dja noticed that,

> this problem is very interesting,

and did the problem without mathematical difficulties, only asking me if it was better to put all the time information in minutes or in hours.

At the beginning, Dja was not grasping the situation posed by the problem. She was not figuring out its authenticity when confronting the situation with her own social experience. As her questions indicate, she was not linking the information presented in the problem with any episode in her life, and, hence, before attempting to solve the problem mathematically, Dja was trying to handle a text which did not represent a discernible circumstance to her. She was stuck in the text, and unable to pursue either mathematical reasoning or performance. But because she was dealing with a mathematical situation, in her view point, what she was not understanding was mathematics. She did not "know how to solve the problem"; however, as soon as the situation posed in the problem was clarified Dja was able to perform correctly. Thus, the mathematical problem invoked in Dja the will to know the social reality proposed in its text.

Problem 2

You live in a city of 70 000 people. 15,3% of the people go to church on Sunday. Only 50% of the church people are Catholic, and only 20% of the Catholic people give money to the church. If those who give money to the church contribute $15 each Sunday for one year (52 weeks), how much money does the church collect? (assigned by the teacher in class).

Dja called me at home to ask if the data condition was correct. I said that it was, and asked her what was the inconvenience of the problem. She said that it was strange that only 15,3% of the people went to the church and then 50%, which is a bigger number, were Catholic. I said to her that she was misunderstanding what was a percentage and that she needed to study that again in order to solve the problem.

Later on, another day, when I asked about the problem, Dja told me that she had done "something"[10], but that she still did not understand the problem. She showed me the problem all correctly done, and when I asked her to explain it to me, she did it clearly; so, I cheered her, but Dja replied:

> I really do not understand this problem. It seems that the problem is turned upside down. It was easier to know at first the total amount of money and then to find out how many people give money to the church.

From Dja's above comment we started to figure out possible situations that might lead into a such problem's enunciation, such as supposing that the money was stolen from the church and consequently, people did not know the total amount of money given to the church. Or, supposing that the church would know in advance the total amount of money that it can count on. But Dja pursued with questions about the manner in which the data conditions were set. She wanted to know how the percentage about the people who give money to the church was found. And, we continued our conversation imagining what were the conditions that would give rise to such a text.

What Dja has reached with her comments was the social fiction of the problem's reality. This is, mathematical word problems, in their attempt to create contexts that present opportunities to deal with mathematical concepts and techniques, sometimes neglect the reality of the situation described in the problem, hence, generating texts that are grounded only in fiction. The above mathematical word problem is an example of this kind of text — as Dja said

> it seems that the problem is turned upside down.

Most probably the situation that one can encounter in social reality is, as Dja also said, that

> it was easier to know at first the total amount of money.

In fact, if the total amount of money that people give to the church is known, since it is also known how much money each person gives (it is part of the problem's data condition), in order to know the number of people that gave money to the church, one has only to divide the total amount of money by the amount of money that each person gives. However, the total amount that the church received is not included in the problem's data conditions. Therefore, the problem's text is omitting the data that corresponds to the most likely reality — the total amount of money that people have already given to the church.

> *Problem 3*
> Aunt Helen is making a 90-inches-wide by 105-inches-long bedspread. She wants to add fringe to the two long sides and one short side of the bedspread. How many yards of fringe should she purchase? (Burton, Hopkins, Johnson, Kaplan, Kennedy, Schultz, 1992, p. 411).

I asked Dja to do the above problem at home, and then explain it to me in our next encounter. When we met again, she told me that she was not capable of doing the problem. I asked her why did she think that she was not able to do the problem. This is her first attempt to explain.

> They say that she wants to put fringe in...
> How much did she?....
> I do not understand.
> They do not say...
> They are not giving any indication,...
> They only say that she wants to put the fringe 90 inches both wide and 105 inches long.
> I do not understand, I do not know.

I asked: What do they not say? What do you think is missing?

> *Dja*: She wants to do a bedspread, and she wants to put a fringe on both the long side and on one wide.
> How many yards of string does she need to buy to do...
> It is not coming to my head.

Here, Dja looked at me, kept silence for a few seconds and did the problem. I kept asking her what was the missing information in the problem's enunciation that she was looking for at the beginning.

> They could have told that she would need to buy a certain amount of string in order to do a yard.
> Like that, it would be easier.
> Because then, I would know how much was necessary for a longside, and then for all the bedspread.
> I think that they did not give enough information about how much string would she need in order to do a yard of fringe.

Again Dja was trying to match the situation described in the problem with her own customs. The particular situation presented in the problem — the making of a bedspread — is common among Capeverdian women; thus, Dja was connecting the problem's information with her experience. However, among Capeverdian women, a bedspread is usually laced, and it includes the lacing of the fringe as well. As Dja's commentaries revealed, she wanted to know the total amount of string necessary to do the all fringe, which firstly required that Dja knew how much string would be necessary to do a yard of fringe. Therefore, Dja was looking for missing information which obviously was not there. The data condition given in the problem was neither enough to solve mathematically the reality that she wanted described in the problem, nor to figure out what could be the solution for the correspondent problem's question. From the initial proposed problem, Dja was creating a new, and more elaborated problem. Thus, Dja's mathematical difficulties were due to her attempt to frame the problem's enunciation in her former cultural experiences.

I asked Dja what happened that made her change her mind and do the problem. She replied

> I mix up mathematics with other things, most of the time with things that have nothing to do with it.

Yes Dja! You are right! In order to solve problems mathematically, the "things" that *we* (not only you) are talking about, 'the things that we are mixing up with mathematics' are not necessary. These "things" that *we* are talking about just serve to unite texts of mathematical problems with broader realities of our lives, and because we are individuals with feelings, pasts, and immersed in socio-cultural contexts, it just happens that when facing a text, sometimes it invokes in our minds aspects of our individuality that we can not hide or refuse. These invocations, although useless in the contexts where we are acting, are, nevertheless, necessary to permit the performance to begin.

In the literature of mathematics education, Spanos, Rhodes, Dale, and Crandall (1988) have identified the influence of linguistic pragmatic features in beginning algebra students. According to these authors,

> students who lack certain kinds of experience, or whose experience has been different from or even contradictory to the experiences presupposed by certain word problems, are apt to encounter difficulties (in Mestre and Cooking, 1988, p. 232).

Dja's initial giving up, or insecurity, about the doing of the above presented mathematical problems, as her interpretations reveal, shows that her personal experience, because it was different from the situation presented by problems, was affecting her mathematical performance. However, when I presented Dja with an opportunity to explain the bases of her lacking of understanding she showed herself as a person who could make sense of the problems, and solve then mathematically.

As Gee, J. (1992) noticed:

> It is an interesting thing about a text that to give its meaning, one has to produce, either out loud or "in one's head", *another text*,(...) This second text is a *translation* of the first text into a "language" (our "own words" or our mental representation) that we take somehow to give the meaning of the first text (p. 13).

The above examples illustrate how Dja was transferring and adapting mathematical problems' texts to her own reality, giving rise to the creation of new texts, therefore showing that mathematical word-problems' texts are susceptible of personal interpretation. The sense that Dja was making of the problems' text conducted her to different problems, whose nature was more cultural and social than mathematical. In problem 1, the lack of experience about the situation described in the problem led Dja to a new problem involving the authenticity of the facts present by the problem. The new focus of attention generated by the context presented in the mathematical problem was disturbing her mathematical performance.

In Problem 2 the difference between Dja's social reality, and the context presented in the problem was confronted by Dja, who, even after solving the problem mathematically, was insecure and insisted that she did not understand the problem.

In Problem 3, the mismatch between Dja's customs and wisdom, and the problem's description, conducted Dja to a new mathematical word problem, which required for its solution more data than originally given.

In conclusion, the data show that mathematical problems are a locus of subjectivity. While interpreting the above problems, Dja invokes the context in which they were designed. By doing so, she is consistently linking her mathematical performance with other contexts, and acting as a person embedded in her socio-cultural realities. However, this subjectivity is neither compatible nor meaningful within the contexts proposed by the mathematical problems, and generates conflicts for her as a mathematical performer.

Or as Dja, herself recognized:

> I mix up mathematics with other things, most of the time with things that have nothing to do with it.

Through these dialogues I have recognized in Dja her desire to be the person that she is when acting in mathematics. Moreover, it was the interaction that I established with Dja that made possible for me to distinguish between simple mathematical failure (what Dja would have shown if left alone in her performance), and different realities (Dja's interpretations) that led into mathematical difficulties. As a mathematics teacher, I have also recognized the need to address what is the nature of mathematical problems that exclude from their doing the possibility of an acting individual embedded in emotions and socio-cultural realities.

The confrontation of student apprentices with mathematical discourse does not occur without tensions. As Pimm (1987) noticed citing Stubb: " a teacher may use a certain style of language, not because it is necessary for expressing certain ideas, but because it is conventional to use it. But the pupils are unlikely to share these conventions" (1987, p. 60). Emerging from this investigation, of particular interest as a locus of discursive tension were mathematical word-problems; Dja, by firstly saying that she did not know how to solve problems, was resisting to tell what word-problems invoked in her mind. Moreover, she later explicitly declared that such invocations have "nothing to do" with mathematics[11]. However, why does Dja think that to expose her feelings and ideas about the problem is not important for its solution?

I will next analyse the characteristics of the language use in the above mentioned texts of mathematical word-problems to localize the features that make them objects of mathematical discourse.

Analysis of word-problems' texts

The common use of word-problems both in mathematics classrooms and textbooks make them a daily tool of mathematical teaching and exchange. Word-problems are verbalized, usually "real-life" based contexts that stand for mathematization. They are presented to students as opportunities to practicize mathematics by having an occasion to change a verbal text into the mathematical symbolic notation.

The word-problems that Dja, firstly, did not know how to solve, or was not sure about their solution, were enunciated by the following texts:

Text 1
A plumber's charge of $90 for a service call includes the cost of the first hour of work. For each additional hour or part of an hour, the charge is $45. What is the total charge for two service calls, one lasting 3 hours 15 minutes and the other lasting 4 1/2 hours?

Text 2
Aunt Helen is making a 90-inches-wide by 105-inches-long bedspread. She wants to add fringe to the two long sides and one short side of the bedspread. How many yards of fringe should she purchase?

Text 3
You live in a city of 70 000 people. 15,3% of the people go to church on Sunday. Only 50% of the church people are Catholic, and only 20% of the Catholic people give money to the church.
If those who give money to the church contribute $15 each Sunday for one year (52 weeks), how much money does the church collect?

An overall configuration emerges from the texts above; it is possible to break each of them into two distinct sections. In the first section a situation is introduced and described. The second section poses a question or questions, regarding the situation previously described.

The texts are rewritten in order to highlight the mentioned characteristics of their organization[12].

Text 1

I — The situation

A plumber's charge of $90 for a service call includes the cost of the first hour of work. For each additional hour or part of an hour, the charge is $45.

II — The question

What is the total charge for two service calls, one lasting 3 hours 15 minutes and the other lasting 4 1/2 hours?

Text 2

I — The situation

Aunt Helen is making a 90-in-wide by 105-in-long bedspread. She wants to add fringe to the two long sides and one short side of the bedspread.

II — The question

How many yards of fringe should she purchase?

Text 3

I — The situation

You live in a city of 70 000 people. 15,3% of the people go to church on Sunday. Only 50% of the church people are Catholic, and only 20% of the Catholic people give money to the church.

II — The question

If those who give money to the church contribute $15 each Sunday for one year (52 weeks), how much money does the church collect?

The textual organization in each one of the above texts, because they clearly separate off the description of a situation from the posing of a question about the situation previously described, suggests that the above texts have the same conceptual characteristics, and two clear distinct moments in that conception.

The language pattern of the above problems' texts is similar. The first sections mainly use the indicative, in its declarative form, (the present continuous is used only once in Text 2). The language is used mainly to convey information, and each time that new information — new data conditions for the problem — are presented, it is "signalled syntactically and lexically"[13]. Thus, no redundancy exists in the text, as each sentence with its new information is "explicitly marked"[14].

The language pattern in the second sections is the interrogative. Therefore language is used predominantly to request information, and it is done through Wh-questions, or using the structure "if...wh-" question[15].

The systematic choice of the indicative either in the declarative form or in the interrogative form, brings on to the reader, as well as to the writer, specific roles. As Rotman (1988, p. 7) noticed by citing (Berry, 1975, p. 166), "The speaker of a clause which has selected the indicative plus declarative has selected for himself the role of informant and for his hearer the role of informed". Because, practically, no alternative verbal mode is used in all these texts, nothing that the reader (or the writer) might know already about the situation which is being presented is evoked or recognized from the writer to the reader as relevant to the text.

Moreover, the use of the indicative is not a strange occasion in mathematical discourse. Rather it is in accordance with its more general discursive features. As Rotman (1988) points out "For mathematics, the indicative governs all those questions, assumptions, and statements of information — assertions, propositions, posits, theorems, hypotheses, axioms, conjectures, and problems — which either ask for, grant, or deliver some piece of mathematical content" (Rotman, 1988, p. 7).

The information in each of the texts is factual, punctual and quantitative: Text 1 describes the cost of a plumber's service; Text 2 presents the dimensions of the bedspread that aunt Helen is doing; Text 3 furnishes information about the number of people who live in a city and give money to the Catholic church.

The texts all display soci ally isolated contexts, with undefined or unknown actors, and vague references to time.

- In Text 1, there is no mention about who calls the service, and there is no reason given for why the service was called. The fact that the plumber's service was called, and one time lasts 3 hours and 15 minutes, and another 4 1/2 hours, is presented as if it is an immutable situation. The undefined "someone" that called the service may be nearby or on other planet, and could have called the plumber's service just now or centuries ago. Moreover, what is supposed to be done by the plumber's service?
- In Text 2, it is Aunt Helen that is doing a bedspread. But sorry, *my* Aunt Helen will never do a bedspread, since she does not like to do bedspreads. So, who is this "Aunt Helen"? She is aunt of whom? Why is she doing a bedspread? With what materials and colours?

In the case of this word-problem, Aunt Helen is doing, now, the bedspread. However, since there is no sense for such an action, the fact that "Aunt Helen" is doing it right now does not really matter. The changing of the text's verbal mode does not affect either the action or the problem's question. The displacement in time is only a matter of tense. As a matter of fact, in the context of this word-problem, "Aunt Helen" could have done the bedspread in the past, or even in the future. Consequently time reference is vague, and fictitious, because there is no more information that substantiates the fact that "Aunt Helen is doing a bedspread" now.

- In Text 3, it is a city, where "you" live, a church in this city, and the Catholic people who give money to the church. All these facts are taken for granted, as if similarities between the real city where *I* live, and the one represented in the text were not more than occasional. But are they? Is that data real? Firstly, *I* may feel it as an imposition. My city is not like that one described in the problem. Consequently, location it not taken seriously by the problems.

In regard to time information the situation is similar to the one found in the previous problem. The verbal mode can be changed without creating constraints to the information presented in the text[16].

Thus, the texts' space-time references for the actions that are being described, if there, are useless and rhetorical. They just appear to help to set up scenarios where unfamiliar actors mimic actions.

In addition, because the information offered by the writer is no more or less than what the reader will need to answer the question (the which is itself posed by the writer), the function of what the writer mentions in the first section of the text is only discovered in its second section after the posing of a question. And, since the answer of such a question is totally dependent upon the previously presented information, the inflection introduced on the text by the question remits the reader back to the already described situation[17], establishing, hence, a closed cyclical type of interaction between the reader and the text that only will end when the question is totally fulfilled. Moreover, such a question is only correctly responded to through the performance of mathematical procedures. Hence, although no allusion is made to mathematics, or mathematical procedures, they are present in a pre-assumed unmentioned context that the text actually demands. Consequently, the contrast reached by the breakdown between given information (first section) and requested information (second section) is more a rethorical distinction than a discursive one, this is, it is not a different topic that is introduced in the second section, but rather the exhortation of a particular look (a mathematical look) into the text's first section.

In conclusion, the above analysis shows that the texts of word-problems make use of the "technology of virtual witness"[18]. This is, the texts are written in such a way that they deviate the reader from the requisite of direct experiencing of what they present. The texts, because they make use of squeezed, simulated real life based situations, with obscure spacio-temporal references, pretend that the reader's experience is already inserted in them, or that, eventually in the future he/she will stumble upon such situations. In so doing, word-problems induce the mathematical performer to eschew the empirical situation, but to imagine that he/she is acting in it. Thus, word-problems' texts can be taken as proposals of "thought experiments" in the sense that they ground an imagining subject rather than an vivid and experiencing one.

Moreover, the textual pattern of the above texts is in accordance with the general features of the formal discursive mode of mathematics, in the sense that, their indexality, if it is there, is fictitious, and they exhort no more or less than the procedures that are required in order to answer mathematically their questions. Therefore, mathematical word-problems only make sense if put within the discursive context where they belong and are embedded. Each text is a microworld that has no existence other than in the mathematical language of objectivity. They can be taken as objects of mathematical discourse. Or, in other words, they can be taken as examples of the language used by the community of practitioners of mathematics to communicate with student apprentices.

I will next examine the interaction established between the above presented mathematical word-problems, and Dja, through the viewpoint of the semiotic model of mathematics.

Facing exclusion: the student apprentice as a Person

The discursive features of word-problems' texts have potential to trigger the processes related to the loss of personal and social reference.

As it was shown above, firstly, the mathematical problem-solver is directed to a hypothetical situation, a scenario, and secondly, she is commanded to act within this scenario. The correct performance expected from the problem-solver is only possible through the exhibition of mathematical procedures. In addition, word-problems' references to the space-time territory of physicality are fallacious, and the actions that they present isolated, and played by unknown actors. They demand for their interpretation an "idealized subject". These mathematical word-problems extracted this student apprentice from her actual arena of reference, meaning, and subjectivity.

In this context, implicated with the mathematical reasoning that will lead to the construction of the different steps required for the problem's solution is the semiotic agency of the "Subject", (the idealized subject addressed by mathematical word-problems) who will make sense of the text by reading it according to the conventions of the mathematical Code, and who will launch the process that makes possible the performance of mathematical procedures[19]. Such procedures are subsequently worked out by the semiotic "Agent" figure, that manipulates signs according to the exact rules of the Code already far removed from concerns of meaning and interpretation[20].

In all the processes of problem-solving, the "Person" is never invoked to act. It is, rather, excluded in the doing of the mathematical activity proposed by word-problems, since the discursive dimension in which the Person operates, the metaCode, is not engaged by word-problems, written as they are in the formal discursive mode of mathematics.

Nonetheless, the accounts of Dja's performance in mathematical word-problems' contexts shows that she was involving in her efforts considerations that are not allowed either to the Subject or to the Agent. Dja was trying to match the scenarios of word-problems with her own experience; she asked about the actors of those texts, about the conditions that gave rise to the problems' enunciations, and she even "saw" the actors as if they had been were placed in her own socio-cultural context. By doing so, she was trying to produce mathematics by acting with the characteristics of the "Person" semiotic agency, as well. However, functioning within the discursive space of the Person was leading Dja to insecurity, or even to desisting from her role as a mathematical performer, because the "new texts"[21] that she was creating were not welcome mathematically; they were not in accordance with the cannons of the formal discursive mode of mathematics where the mathematical activity proposed by the word-problems take place.

As Rotman says,

> only on the basis "it is like me" is the Subject in a position to be persuaded that what happens to the Agent in its imagined world mimics what would happen to the Subject in the actual or projected world. But it is this recognition, this judgment or affirmation of sufficient similitude, that the Subject cannot articulate, since to do so would require access to an indexical self-description necessarily denied to any user of the Code (1993, p. 78).

It was this kind of authentication, this kind of "it is like me" that Dja was seeking when trying to figure out possible relationships between the situation that she was encountering in word-problem's text and her own realities. Before trying to discover such a similarity, Dja did not allow herself to be convinced by the proposal of the mathematical word-problem, and consequently she inhibited her passage to the scenarios where the Subject and Agent act in isolation from the Person[22].

As an apprentice of mathematics, Dja was looking for an "underlying story", some "idea behind the problem"[23] that would acknowledge the mathematical problem (that is the thought experiment), and subsequently empower the imagining of what it proposes, and the acting out of what it demands. Thus, in the particular cases of the above problems, the presence of the Person represent meaningful and necessary mathematical reasoning[24].

It is time now to extend these considerations further and address the conditions and unconscious processes that lead students to abandon their attempts to understand and complete mathematical word problems.

The above sample of problems was collected from three different places; two different contemporary mathematics textbooks, and Dja's classroom materials; hence, they can be taken as a diverse sample. Even so, their discursive characteristics are similar.

If the above word-problems are each taken from the template of the formal discursive mode of mathematics, and as such call for a disembodied performer, when they are looked upon from the viewpoint of the interaction established between them and the performer, word-problems' texts do invoke individual images and questions, and as such, they create a unique situation. In this context, mathematical word-problems have a dual existence; even if they demand a transcultural mathematical performer, they also arouse his or her subjective nature. When asked to solve a mathematical word-problem, it is this perplexing dual characteristic of word-problems that the student-apprentice may face.

In addition, what the performer beforehand "unconsciously knows" is that, in mathematical activities, acting as a subjective, culturally and socially embedded actor is avoided. After all, present day mathematics is deeply founded in, and supported by practices grounded in the misuse of the metaCode, the only discursive dimension that makes possible the acting of the Person. Consequently, the unconscious aspect of the practice of abandoning attempts to solve a mathematical word-problem can be interpreted as a demonstration of the implicit knowledge that the student apprentice arrives at: that the revealing of subjectivity in mathematical contexts will never be taken seriously, and even collides with present day culture of mathematics. The mathematical community already shares practices that denote the metaCode to a place of subalternity, or even denies its existence, in relation to the Code[25]; the student apprentice, on the other hand, is not yet a member of this community, and most likely will never be, and is still in the process of being enculturated in its practices. Being so, the student is still developing the "habitus" that will "produce the practice" (Bourdieu 1977, p. 78) of denying the invocations incited by the ambivalent nature of word-problems. That is, contrary to a person who is already fluent in mathematical discourse, and as such has already acquired the "habitus" that permits to prompt the Subject's incarnation in order to enact the scenarios of mathematical word-problems exactly as they demand, the student apprentice as a mathematical problem solver still allows subjective realities to affect his or her performance. After all student apprentices are only starting the mathematical training of "forgetting"[26] about themselves, and their surrounding realities.

As it was shown above, word problems represent thought experiments, however, contrary to what happens among the community of mathematicians, where mathematicians can speak about a dream, students apprentices encounter in word problems thought experiments that are already set up. That is, students face in word problems situations whose simplified reality has already been formed and adapted to the formal discourse of mathematics, without their having participated in such a production.

Dja's mathematical malfunction in the above word problems was not located within her performance as the Agent semiotic figure, or even in the passage from the Subject to the Agent, but rather in the passage from the Person to the Subject.

Final considerations

Pedagogical implications

This investigation examines the relationship of Dja, a 14 year old female student, with mathematics. I search the nature of Dja's problematic performance on word problems whose mathematical content already belongs to her repertoire.

What emerges from the present investigation is that the student's mathematical performance is linked with the problematic of cultural encounters that exist between the society of practitioners of mathematics and those who do not belong (yet or never) to this community. The malfunctions of the mathematical problem solver can be interpreted as a broader type of cultural tension that arises when she is encountering a discourse that excludes the possibility of her participation as an embodied Subject, a Person. Mathematical discourse — and more concretely word problems — alienate the possibility of the student's drawing on her own emergent local realities, indeed, her own culture, when she is performing her role as a mathematical problem solver. Her feelings of strangeness toward mathematics can be linked with the requirement of the mathematical discourse, that cultural references and emotions must be deleted in enacting the imperative orders and the transcultural attributes that characterize the discursive features of the Code. After all, it is the Code's primordial position within mathematics that forces the student into a position of outsider in relation to mathematics, by not tolerating in its discursive characteristics the student's self expression and cultural embodiment.

As it was shown above, the participation of the Person in its multiple facets in the doing of word problems has a direct impact on the correct performance of the other semiotic agencies, that is, the Subject and the Agent. In other words, the Person's participation has repercussions in the mathematical performance that takes place within the Code as well: after all, Dja's mathematical incomprehension was transformed into success after I pushed her to act as Person. Thus, the disregard of the subjective nature of the performer in mathematical practices has to be addressed as a factor that influences the problem solving itself.

As noted earlier, contemporary conceptions of mathematics do not consider as mathematically important the discursive dimension of the metaCode: nonetheless, as Rotman argues (1993), the metaCode (where the Person is allowed expression) is not only essential, but also broadly used by mathematicians themselves, side by side with the other semiotic agencies, when they are doing mathematics. In the last decade, mathematics education has been attempting to recognize the role of classroom discourse in general as a context for apprehension and development of mathematical knowledge. Experts have stressed the centrality of the discourse's role (defined as "the ways of representing, thinking, talking, agreeing and disagreeing") to the display of mathematics's specific forms of "knowing" (NCTM, 1991, p. 34). Within this frame, the teacher arises as a key figure not only in the production of a classroom environment that encourages students to generate discourse, but also in the "orchestrating" of such discourse (NCTM, 1991, pp. 34-45). Also, the teacher's "appreciation of, and respect for, students' diversity" (p. 34) is pointed out as a basic requirement for the creation of classroom discourse. Moreover, this professional mathematics group have also highlighted the importance of diversified "tools for enhancing classroom discourse", that range, for example, from "computers" to "oral presentations and dramatizations" (p. 52).

Despite such an emphasis on the role of discourse in general in classroom mathematics in opening up the possibility of students' participation in mathematics as culturally and socially embodied individuals, the role of the discourse in mathematics classrooms still is not informed by a thoughtful theory that accounts for the presence of the Person in mathematical activity. In particular, the malfunctions of the mathematical problem solver, that ultimately are reflected in school grades, and consequently lead to the wide lack of public mathematical literacy, still need to be informed by an explanatory framework that accounts for both Code and metaCode, and the linkage between them, within mathematical discourse.

Since the metaCode is inhabited by temporally endowed "Persons", it also admits the subjective nature of the mathematical performer into the process, empowering the linkage between each individual universe of references and the universe of mathematical procedures, methods, and problems. Consequently, students can bring their culture and social references into problems' enunciations, as well as into their solutions, so that the teacher can promote further movement into the discursive dimension of the Code.

In a theoretical framework that makes use of the Person to explain the doing of mathematics, mathematical performance difficulties pointed out in mathematics education literature as grounded in students' lack of experience or different experience, for example, in regard to whatever situation word problems describe, may now be open to easier resolution. The search for different interpretative possibilities of a problem's enunciation, as well as its adjustment to the formal discursive mode of mathematics, now becomes part of mathematical reasoning itself. That is, once all three semiotic agencies are required by mathematics education to be a part of the doing of mathematics, the inclusion of the Person, as well as the inclusion of the process that accomplished the passage from the Person to the Subject, will be faced as tasks of mathematics education as well. Consequently, rather than being the basis for additional difficulties to the performer, the confrontation of each student's reality with the problem's enunciation, will be a part of the step by step production of mathematical reasoning itself. In order to foster the knowledge required by the mathematical Code, it is necessary to direct the student toward the attributes of its discursive dimension, and to produce discourse to support the Subject's incarnation. This necessarily means allowing the enactment of the Person, and guiding her passage to the Subject.

In addition, it is important to remember that the "Person" is not only a culturally standardized individual, but also that other elements of experience, such as biography, gender, family, class, intentions, expectations, and feelings all contribute to shape the unique features of the Person. In order to articulate between the realities that are behind each student's vision of the problem, and the mathematical resolution of the thought experiment proposed by word problems, the teacher needs to cross very broadly into the student's universe of references to encounter that which is blocking the understanding of the task. Only thus can the difficulty be handled from the view point of mathematics. It is thus, the broad discursive encounter between students and teacher, and even students and students that this investigation points to as features of the highest pedagogical relevance. Moreover, the contingent nature of the factors implicated with such encounters is not compatible with suggestions of specific techniques or methods.

In order to make mathematics a familiar and accessible subject matter, grounded in experience, and socio-culturally embedded, it is indispensable that students participate in mathematical accounts, and take their own realities as locus and leitmotif for mathematical representation. That is, the challenge of mathematics education is to produce discourse to interpret the complex daily realities of persons and finally to simplify them by transposing them into the specific language of mathematics. Only thus can native language be transformed into mathematical language itself.

Further research

Future research should focus on further development of theoretical frameworks that can elucidate the influences of mathematical discourse and perhaps other forms of scientific discourse on student apprentices. This work will have to be accompanied by the development of methods for gathering empirical evidence for demonstrating how mathematical activities are locus of practitioner's subjectivity, as well as how such subjectivity is related to mathematical performance.

Inquiry into present day professional mathematicians' practices is essential. An ethnography of mathematics as a professional activity has yet to be done. Such an ethnography is necessary to inform a realistic representation of mathematical practice for those who are not mathematical practitioners. This audience includes, of course, student apprentices, but also the broader public who need more understanding of the critical importance of mathematics in contemporary society.

Notes

[1] I taught in Lisbon, Luanda and Praia — the main cities of these countries.

[2] That is, mathematical practices are based on the conception of experiments, rather than in experimentation itself.

[3] As Rotman himself remarked, " The formal or rigorous mode — privileged as mathematics 'proper'" (1993, p. 69). In addition, both knowledge that arises from the informal mathematics and formal mathematics has been recognized in the last decades as playing an important role in the construction and development of mathematical knowledge. See, for example, Davis & Hersh (1982); Bloor (1991), and Lakatos (1976).

[4] These processes are depicted in two categories of functors, respectively, the "forgetful" functors and the "limit" functors (Rotman, 1993, p. 92).

[5] Rotman's terminology (p. 80).

[6] According to Pimm, these are common expressions in mathematical explanations.

[7] Pimm's terminology.

[8] The supposed lack of giftdness is also a folk, common-sense justification for this kind of failure to perform.

[9] It was not easy for me to reject a request from Dja; but I thought that her own translation also could be a clue for me to understand Dja's difficulty with the problem.

[10] Dja's words.

[11] Dja's words.

[12] According to Gee (1990) in order to analyse a text from a discursive point of view, it is necessary to consider five interconnected subsystems, each one accounting for certain characteristics of language, that altogether confer to a text the possibility of being understood, interpreted and located among the social network who produces it (Gee, 1990, p. 104). The five sub- systems are; prosody, cohesion, contextualization signs, thematic organization and discourse organization. Gee's theoretical framework underlies the conception of the following textual analysis.

[13] Expression used by Scollon & Scollon (1981, p. 48).

[14] Expression used by Scollon & Scollon (1981, p. 48). These authors also remarked that texts with such features take the reader as if "the "reader" is not any ordinary human being. It is an idealization, a rational mind formed by the rational body of knowledge of which the (text) is part. The reader is not allowed lapses of attention or idiosyncrasies" (1981, p. 48).

[15] Wh- questions refers to questions beginnig with words like: when, where, what, ...

[16] As examples, these problems are written in the past.

Text 2

I — The situation

Aunt Helen made a 90-in-wide by 105-in-long bedspread. She wanted to add fringe to the two long sides and one short side of the bedspread.

II — The question

How many yards of fringe did she purchase?

Text 3

I — The situation

You lived in a city of 70 000 people. 15,3% of the people went to church on Sunday. Only 50% of the church people were Catholic, and only 20% of the Catholic people gave money to the church

II — The question

If those who gave money to the church contributed $15 each Sunday for one year (52 weeks), how much money did the church collect?

[17] The reader will look again to problem's text, now, to interpret it from the question's viewpoint.

[18] As it was noticed by Rotman, "the technology of virtual witnessing" was a term used by Steve Shapin and Simon Schaffer (1985) to refer to " a carefully constructed way of writing and appealing

to pictures and diagrams which, by causing "the production in the reader's mind of such an image of an experimental scene as obviates the necessity for either direct witness or replication" (1985, p. 60), allowing the "facts" to speak for themselves and be disseminated over the widest possible arena of belief" (Rotman, 1993, p. 67).

[19] More concretely, the Subject will figure out what mathematical procedures and operations the problem requires for its solution.

[20] That is, the Agent will operate the "counts".

[21] Gee's terminology.

[22] After the solving of the problem, an occasion exists when the mathematical performer has access to the Person; to revise the agreement between the textual narrative of word-problems and her mathematical conduct, which eventually will repair the malfunctions of the Agent and Subject. In fact, only within this discursive dimension of the Person can self-inquiry about the correctness and adequacy of mathematical operations exist.

[23] As Rotman argues, when mathematicians face a new proof, they "often before anything else- ask for and try to find the idea behind the proof. They will want to know the principle, concept or underlying story that organizes the separate logical moves presented to them" (1993, p. 80). In this search, the Person becomes active in their mathematical activity.

[24] I am referring to mathematical reasoning in Rotman's sense.

[25] Which is a part of an historical process of mathematics, and it is already deeply imbued in its discourse: thus, it is unconsciously practicized.

[26] Rotman's terminology (1993, p. 91).

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RESUMO. Esta investigação examina desempenhos problemáticos de Dja, uma aluna caboverdiana do programa bilingue de português/inglês, em problemas matemáticos. A incompreensão da aluna face aos problemas é descrita e analisada emergindo a natureza subjectiva do actor matemático. O modelo semiótico da matemática (Rotman, B., 1993) é utilizado no enquadramento da relação da aluna com os problemas. Mostra-se que os problemas são exemplos do discurso formal da matemática, logo excluindo a actividade da "Pessoa", como figura semiótica, do seu desempenho matemático. Tal exclusão está na base da relação hesitante existente entre a aluna e os textos dos problemas, e, de um modo mais geral, entre a aluna e a *matemática.*

A actuação de um aluno, preenchido culturalmente, na actividade matemática, é a principal sugestão pedagógica desta investigação para promover o movimento do aluno ao acesso do discurso matemático formal.

ABSTRACT. This investigation examines the nature of the problematic performance of Dja (a 14 years old female Capeverdian student in a Portuguese/English bilingual program), in word problems whose mathematical content belonged already to her repertoire. The student's incomprehension toward problems is described, and analysed. It emerges that word problems may induce the subjective nature of the mathematical performer. Brian Rotman's semiotic model of mathematics is applied to examine the nature of the student's relationship with word problems. It is shown that word problems are examples of the formal discourse of mathematics, therefore excluding the Person, as semiotic figure, from mathematical activity. Such a separation is at the basis of the student's problematic relationship whit the written texts of word problems, and with mathematics more generally.

To bring the student as a culturally embedded person into the activity of mathematics, as a mean to promote movement into its formal discursive mode, is the major pedagogical suggestion of the investigation.