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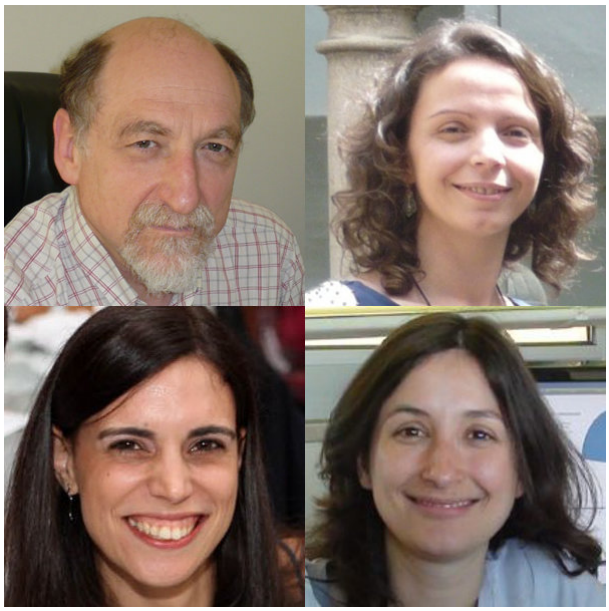

Designing lesson studies to support teachers' professional development

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Abstract

In this paper we address design issues of lesson studies that aim to support practicing teachers' professional development. We discuss these issues based in the cases of two lesson studies that we conducted in the academic year of 2013-2014 in a cluster of schools in Lisbon. We strive to show that, besides the consideration of the mathematical content, task features, and focus on student reasoning, attention needs to be paid to organizational issues regarding the way the teachers are invited to become involved in lesson studies and to the collaborative environment provided. We also conclude critical design factors for the success of a lesson study include the investigation style of the whole activity, the combination of teachers' experiential knowledge with research knowledge, and the exploratory and collaborative environment that frames the activities that the teachers undertake.

Introduction

Lesson study is a process that is increasingly used for teachers' professional development. It takes place within the school environment, with teachers playing a central role. Usually, it begins with the participants identifying a relevant issue related to students' learning. Then, the teachers plan a lesson together considering curriculum guidelines and relevant research findings, predict possible students' difficulties, formulate teaching strategies, design or select tasks to propose in this lesson, anticipate questions that students may pose, and prepare procedures and instruments to observe the lesson. This

research lesson is typically taught by one of the teachers while the others observe and take notes paying special attention to students' learning. Afterwards, the teachers meet to analyze and reflect on the observations carried out. The analysis may lead to the reformulation of the lesson plan, to change the strategies and materials used, the tasks proposed, the questions asked to the students, etc. Frequently, a revised lesson is later taught by another teacher to other class, and this may be repeated in several cycles (Lewis, Perry & Hurd, 2009; Murata, 2011). By participating in lesson studies, teachers may learn about important professional issues in relation to their subject, curriculum guidelines, students' reasoning processes and difficulties, and classroom management (Lewis, Fischman, Riggs & Wasserman, 2013).

Research has addressed possible adaptations of the original Japanese model to other countries (Lewis et al., 2013), addressing for example the role of experts (Huang, Su & Xu, 2014) and of teacher-leaders (Perry & Lewis, 2009). However, the dynamic of a lesson study and how it relates to the culture of different countries tends to be absent from research reports. Lesson studies are dynamic social collaborative processes with specific organizational features and their unfolding may give rise to unforeseen issues that may have a strong influence on the outcomes of this process for the participating teachers. In this paper we present key design features that we used in two lesson studies and analyze emerging issues, discussing their implications for conducting this professional development opportunity.

Features of lesson studies

A central aspect of lesson studies is their focus on students' learning and not on the teachers' activity. This distinguishes lesson studies from other professional development processes which focus mainly on what teachers do (Cajkler, Wood, Norton & Pedder, 2014). Indeed, lesson studies aim to examine students' knowledge and difficulties and to better understand the way they learn. A successful lesson study depends on several conditions: (i) a group of teachers who are interested in learning from such experience and have the time and personal conditions to do so; (ii) logistical conditions regarding a common meeting time for participating in the regular sessions and for teaching and observing the research lesson; (iii) authorization from the school administration and other authorities; and (iv) suitable leadership to conduct the lesson study process.

Despite their common core processes, lesson studies conducted in different countries and settings differ in many features. This is a natural phenomenon, since the local conditions and the aims of participants may be quite different. For example, lesson studies may differ in purpose – is the aim to promote teachers' professional development or does it

serve mainly a research purpose, seeking to generate knowledge about students' learning, tasks, classroom processes? They may also differ on who takes the initiative – is it the participating group of teachers, one or more teacher educators or researchers, or the school administration? All these cases may lead to successful lesson studies, but if the initiative is external to the participants, it is necessary to make sure that they are aware of the process and have the interest and disposition to carry out the activity as expected. Lesson studies may also differ in terms of leadership, which may be internal to the group or assumed by an external person, such as an experienced teacher, a teacher educator, or a researcher. Lesson studies may still differ on who are the participants – just practicing teachers, or also members of the school leadership, teacher educators and researchers, preservice teachers, and even other people. They may also differ in many aspects of the format and length, concerning the way the leading issue is framed (from inside or outside the group), the depth of the preparation of the research lesson (with more or less attention to curriculum guidelines, previous research studies and diagnosis of students' background knowledge), the observation of the research lesson (more holistic or more structured by data gathering instruments), and the work done subsequently to the research lesson (revising the original plan and re-teaching the lesson, continuing the analysis of the lesson, or applying the knowledge generated in the process to other lessons).

In our case, lesson studies are conducted mostly with a research purpose: we want to understand what teachers may learn by participating in this process and also what are the features of lesson studies that may strengthen its value as a learning opportunity. The lesson studies that we conduct have been from our own initiative, as we approach teachers in particular schools or belonging to particular groups and challenge them to get involved in this process. The leadership of these lesson studies is undertaken by our group, usually with one member in charge of conducting the sessions with the support of the whole research team. In the cases reported in this paper, the participants are practicing teachers but we have also conducted lesson studies with prospective teachers. The format and length of our lesson studies also have some key features.

i. The planning of the lesson is quite detailed with the main emphasis on surveying the different kinds of tasks that may be proposed to students and the difficulties that such tasks may elicit, and this is done by undertaking a lot of mathematical work (solving tasks) and didactical work (discussing teaching and learning issues).
ii. The planning takes into account the curriculum guidelines and findings from previous research.

iii. An important element of the planning is the diagnosis of students' previous knowledge and difficulties on related topics.
iv. We provide a set of follow-up sessions in which teachers are challenged to apply what they are learning in this experience to other lessons.

Lesson studies may differ in the curriculum approach in which they are conducted, that may stress different kinds of learning aims for students, with different kinds of tasks and guidelines for the structure of the mathematics class. We carry out lesson studies within the curriculum framework of exploratory learning, which means that the students work on tasks in which they have to construct their own solving strategies, using several mathematical representations flexibly. Whereas in the usual classroom the teacher first teaches procedures and algorithms, showing examples, and then proposes exercises to practice, in the exploratory approach the teacher proposes for the students mathematical work that may lead them to reconstruct concepts, representations and mathematical procedures. This approach is geared to promote students' mathematical reasoning, especially when students make conjectures and generalizations (inductive and abductive reasoning) and justifications using mathematical properties, definitions or representations (deductive reasoning) (Ponte, Mata-Pereira, Henriques & Quaresma, 2013). To achieve that, the teacher promotes frequent moments of collective discussion, with negotiation of meaning and argumentation. In this way, the teacher seeks to lead the students in developing their reasoning, their understanding of mathematics and the ability to use it in different situations. The exploratory approach emphasizes the construction of concepts, the modeling of situations, and also the use of definitions and properties of mathematical objects to arrive at conclusions. Attention is paid to computational aspects, but also to conceptual issues. This approach is similar in many respects to what other authors call "inquiry-based mathematics teaching" (Artigue & Blomhøj, 2013), "guided reinvention" (Gravemeijer, 2005), "landscapes of investigation" (Skovsmose, 2001), or "reform mathematics" (NCTM, 2000).

The exploratory approach requires that the teacher proposes suitable tasks in the classroom. If the task is too easy and the students know how to solve it right away, they will learn nothing. If the task is too difficult, the students probably will give up quickly in solving it. So, tasks must have an appropriate level of challenge and must support students' learning of some mathematical idea. Usually, exploratory lessons develop along three phases (Ponte, 2005): (i) presentation of the task and its interpretation by students (as a whole class); (ii) development of the work by the students (in groups, pairs or individually); and (iii) discussion and synthesis (again as a whole class). This last phase is very important since it allows the emergence of connections and the development of

meanings (Bishop & Goffree, 1986), enabling students to relate several topics and showing how mathematical ideas are interrelated. In addition, the moments of collective discussion constitute opportunities for the negotiation of mathematical meanings and the construction of new knowledge. Learning mathematics with understanding develops with classroom interactions, as students suggest mathematical ideas and conjectures, and learn to evaluate their own reasoning and the reasoning of other students. This can be achieved if working on each task culminates in a moment of collective discussion to reflect on the work done, discuss ideas, processes and conclusions (NCTM, 2000).

The approach that we use for teachers' professional development is also exploratory. That means that, instead of saying to teachers what they should do, we strive to set up activities that create opportunities for them to discuss and to arrive at conclusions about how to act in the classroom. To achieve it, we seek to organize frequent moments of discussion and reflection regarding important issues as well as to create opportunities for teachers to use in their own classrooms the ideas that they are learning by participating in the lesson study. In the lesson study process we strive to create a collaborative environment among the teachers, including ourselves in the group. Therefore, we suggest the teachers carry out tasks together, within sessions and between sessions, and we try to create a friendly atmosphere, making proposals and negotiating the tasks to do and how to do them.

Method

The two lesson studies that we present in this paper were conducted in the academic year of 2013-2014 in a cluster of schools in Lisbon, which included two primary schools (grades 1-4), a middle school (grades 5-9) and a secondary school, (grades 7-12). The principal of the cluster had a project for the improvement of the teaching of mathematics and Portuguese language, requesting the collaboration of the Institute of Education (IE) of the University of Lisbon. In a meeting with the principal and other members of the school team, we proposed to conduct lesson studies to address their concerns. The principal agreed with the proposal and one of the lesson studies was carried out with seven primary teachers (grades 3-4), another with five middle school teachers (grades 5-6), and a third with five secondary school teachers (grades 7-9).

In a meeting that included the principal, the primary school coordinator, the leaders of the middle school group and of the secondary school group, and our team, it was decided that the lesson studies would focus on topics from grades 3, 5 and 7, bearing in mind that a new syllabus was just being introduced at these grades. The IE team that conducted this work is comprised of four members: Marisa led most sessions in the three cases, Joana

helped leading grades 5 and 7 sessions, Mónica acted as an observer and João Pedro coordinated the whole process and participated in some sessions. In addition, Vanessa de Andrade acted as a research assistant in data collection and transcriptions.

In this paper we focus on the grade 3 and grade 5 lesson studies. At grade 5, the principal appointed one of the teachers, Maria, as the coordinator of the group, but there was no official coordinator for the grade 3 group. Note that all teachers' and students' names in the paper are pseudonyms.

In all cases, the lesson study sessions took place once or twice a month, a somewhat slow pace that was proposed by the teachers who had many other concurrent activities and responsibilities. Session 1 aimed to introduce the lesson study to all participating teachers. Sessions 2 to 6 intended to deepen their knowledge about the chosen topic and about diagnosing students' previous knowledge (including the realization of a diagnostic test) and to prepare a class on it. Session 7 consisted in observing a lesson, and session 8 was a reflection on the research lesson and about the work carried out up to that point. In sessions 9 to 12 we asked the teachers to plan, carry out, and reflect about two classes following the previous work undertaken. In session 12 there was also a global reflection about the whole work carried out.

For this study, data was gathered by audio recording of all sessions, video recording of the research lesson, plus individual interviews (just after session 8) and a focus interview (in session 12), a final written reflection from each teacher, collecting teachers' productions (such as lesson plans) and a researcher's journal. The tasks analyzed in the lesson study sessions were in some cases proposed by the research team and in other cases proposed by the teachers. The task proposed in the research lesson was constructed by the participating teachers by transforming and adapting tasks that they found elsewhere. Data analysis begun by identifying significant moments in the different sessions regarding unexpected events or regarding the teachers' perspectives about the tasks to propose to their students or about their interpretations of students' work. From this set of episodes, we present an analysis of those that we found more informative regarding the aims of this paper, presenting our story as a narrative (Bruner, 1991; Riessman, 1993). Note that all the data presented in the paper was originally in Portuguese and has been translated to English.

A lesson study at Grade 5

This group was made up of five middle school teachers (Francisca, Luisa, and Maria, who taught grade 5, and Irene and Tânia, who taught grade 6), all from the same school.

Maria, who was appointed as the group coordinator, attended a preparation meeting where we explained our working proposal. In the first session of the lesson study, we discovered that the participating teachers were not very interested in doing this activity, which they looked on with strong mistrust, and they preferred to be involved on a more usual professional development activity. However, the activity carried out in the following sessions quickly created a strong involvement from teachers. But the selection of the teacher to teach the research lesson created further concerns among the teachers. When the decision was made, and a teacher was finally selected, the group became quite cohesive and the work progressed on a fruitful way.

A difficult beginning

In session 1, we presented lesson study giving examples of Japan and the USA. As the purpose and format of the lesson study had already been presented and accepted in a previous meeting with Maria and the principal, we thought that all the teachers were informed about it. However, they showed a lot of uneasiness regarding this process. Assuming the role of coordinator of the group Maria made insistent interventions, asking, for example, “Is it justified to spend such a long time just in addressing one topic?” She also pointed out the likely discomfort of the students with so many observers in the room. The questions went on and on. We were caught by surprise and sought to respond to the various questions, justifying the proposal by noting that it was very useful to study in depth the way to teach a difficult topic and also that our past experience showed that the students were not disturbed by having many observers around and forgot about them (Ponte, Baptista, Velez & Costa, 2012). At some point, Maria directed her concerns to the role of the teacher of the research lesson. She asked if “the teacher also forgets” that he or she is being observed. It was clear that the teachers had great discomfort with the possibility of being observed. They likened this process to the teachers’ evaluation processes, both for prospective and practicing teachers, as Maria complained, “I’m going to feel observed and evaluated”. We pointed out that, in lesson study, unlike other cases, the focus of attention is on the work of the students and not on the work developed by the teachers. Finally, after many arguments, the teachers agreed to proceed with the lesson study.

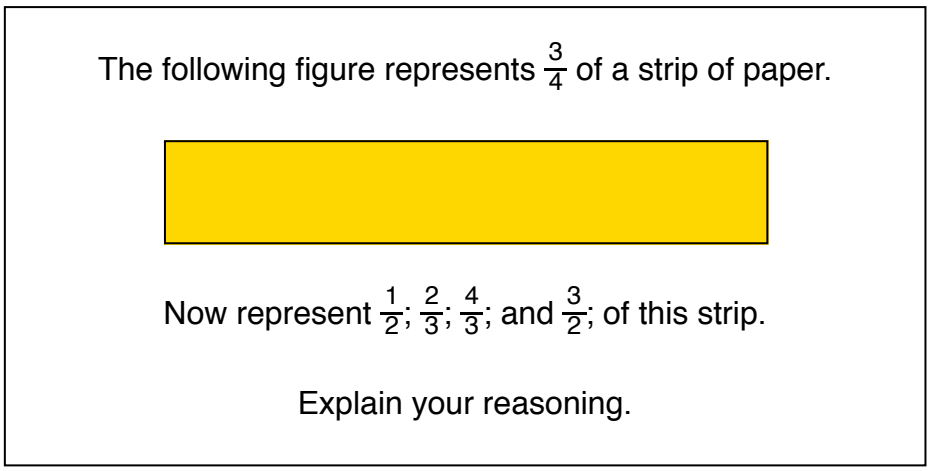
We thought that this beginning could not have been more troubling. When the session was over we had serious doubts about whether this lesson study would come to eventuate. The teachers knew each other but we noted that there was some distance among them. Maria was much more questioning than the other teachers but we felt that all of them were evaluating negatively what we were proposing to do in the coming sessions. Noting

that this group was just formed to carry out the lesson study, we concluded that a lot of attention was required concerning the construction of a collaborative working environment. We decided that Maria, as the group coordinator, should be regarded as the key element to help in developing this environment.

Working with mathematical tasks, anticipating students' answers and diagnosing their knowledge

The topic for this lesson study was rational numbers. In session 2 we proposed several mathematical tasks for the teachers to solve and think about possible students' difficulties. The teachers did not know the task indicated in Figure 1 and it provided a discussion with much participation:

Figure 1: Task analyzed by the teachers in session 2



Maria quickly asked:

> *How would you approach this? This is $\frac{3}{4}$ and now how would you ask $\frac{1}{2}$? How will they [do]...?*

This question generated an interesting discussion, first about solving the task:

> **Tânia:** *First try to add...*
> **Irene:** *One divides this part...*
> **Marisa:** *First they realize what is...*
> **Teachers:** *[At the same time] the unit!*
> **Tânia:** *That this is not a unit.*

The teachers sought how to reason and indicated how to solve the task. They recognized that the task was difficult, requiring from their students a solution with several steps, beginning by the reconstruction of the unit.

After they solved the task, the teachers thought about the ways that the students could think about it and discussed their possible difficulties, pointing out what could be the most common mistakes:

Maria:	*They readily divide it into four.*
Teachers:	*Yeah, exactly!*
Tânia:	*And that's because they do not know yet... They do not know yet the notion of... They do not have the notion of the fraction as a part of a whole.*
Joana:	*In fact, they often work in the opposite way, that is, they have the whole and they have to indicate a part. Now have the part...*
Marisa:	*And to indicate the whole is a major conceptual leap.*
Luísa:	*Yeah, yeah.*
Maria:	*Very big!*

During the lesson study, on several occasions, the teachers discussed students' learning in relation to the nature of tasks. For example, in session 3, in a discussion about different kinds of tasks, the teachers related the work that they were doing to previous exploratory work they witnessed in the classroom. Referring to the angle sum of a triangle, Luísa recalled the activity of the students: "they cut and glued in the notebook and then they said, 'Ah! This is a straight angle' Francisca added: "and they do not forget! It is very funny, they remember." Both Luísa and Francisca valued the exploration carried out with concrete materials and emphasized that such manipulation and discovery was important for their students' learning.

Solving mathematical tasks that challenged or involved some element of novelty and identifying possible students' difficulties in a thorough and systematic way was new for these teachers. This seems to have contributed to their change of attitude towards and interest in this professional development model. From the second session on, the teachers began to engage enthusiastically in the tasks that we proposed in the lesson study sessions.

One of the aims of session 3 was to produce a diagnostic test that could provide information for the research lesson. The planning of this session included the definition of the main aspects of this test and the selection of tasks. All teachers were actively involved during this session. They divided the labor, bringing tasks on different issues for this session. Discussing and preparing the test was really hard work and close to the end of the session Maria noticed the time and exclaimed "much time has elapsed, hasn´t it? It does not seem so!" At the end of this session we had the impression that there was now a

climate of confidence among the teachers and teacher educators, which is critical for the success of a lesson study.

In session 4 the results of the diagnostic test were discussed. Several weak points of the previous knowledge of the students were noted, including reading and writing rational numbers as decimals, comparing fractions and decimals, ordering numbers represented as fractions and decimal and natural numbers and representing fractions and decimals in a number line. The diagnostic test also showed that the students already understood pictorial representations well and converting pictorial, fraction and percent representations in simple cases. They had the notion of unit and were able to complete it with ease and knew about equivalent fractions (based in the pictorial representation). An important outcome of this work in diagnosing students' knowledge was the recognition that, besides their difficulties, they could very often design and put into practice rather clever unexpected strategies for dealing with tasks.

Who will teach the research lesson?

The identification of the teacher who would teach the class generated strong embarrassment in the group from the very first moment. The decision was finally taken at session 5 and it was not an easy one. Only three teachers taught grade 5 classes, Maria, Luísa and Francisca, so it had to be one of them. The need to make a decision became stronger as the lesson study progressed and it created noticeable discomfort. Francisca began by saying that her two classes had too much misbehavior and, therefore, the research lesson could not be hers and Maria was absolutely negative regarding doing the research lesson.

Francisca:	*Since the very beginning I have said this – in my [class] it is impossible.*
Luísa:	*Mine is not [suitable], but…*
Marisa:	*It may also be a challenge. [silence]*
Luísa:	*By me…*
Marisa:	*I do not know. We will go to any of yours.*
Maria:	*If Luísa does not mind it is decided. Right, Luísa?*
Luísa:	*You are getting the worst class. I think it is worthwhile to do it in two [classes]…. One well behaved and one poorly behaved.*
Marisa:	*Can it be yours [Maria]?*
Maria:	*Not mine, because I do not want it. [silence]*
Luísa:	*So, it will be in mine. [silence]*

Given the discomfort of Francisca and Maria, Luísa ended up offering herself to teach the research lesson. Recognizing the difficulties of the students and the enrichment that such experience could provide for the group if carried out in two classes. Luísa suggested that another class could also be chosen to carry out the research lesson. This idea was not well accepted by her colleagues who repeated their previous arguments. Maria voiced again the issues that she had raised at session 1, when she said that she did not want to be evaluated.

Before this decision was taken there was some instability in the group of teachers. Afterwards, the mood in the group became much quieter. The attention focused on the preparation of the research lesson and consequently on the teacher who would teach it, but the other teachers remained strongly involved and committed to the decisions that were necessary to take regarding how this lesson should be carried out.

The research lesson

In the research lesson, despite the careful preparation, the students did not reach the aims planed by the group – generalization of the rules to compare fractions with the same denominator and with the same numerator. However, the students "discovered" equivalent fractions. In the reflection about the whole class discussion, as a positive aspect, Luísa highlighted the fact that, despite the fact that was not planned, she discussed this notion with the students:

> *So, one of the most interesting things was that they grasped equivalent fractions; they picked up the representations and found equivalent fractions without even knowing the name. It was more like that, it was positive.*

Tânia also agreed that this was a very positive aspect of the lesson and added the discussion about the notion of unit:

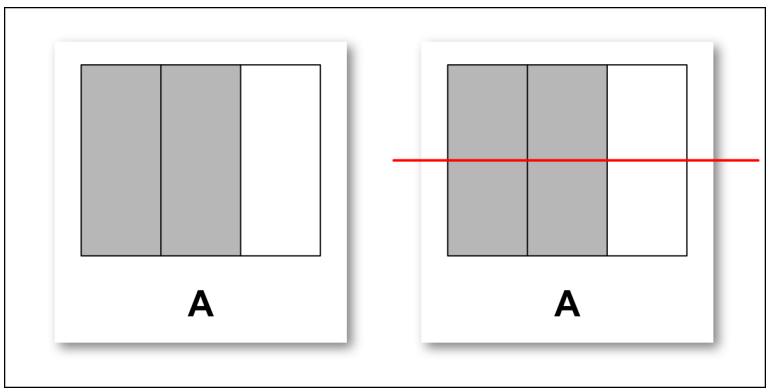
> *It was, also. Equivalent fractions and fractions that represent the unit, they turned out to emerge, didn't they? And then several appeared. Also Luísa was... She picked the idea from whom I do not know [Marisa: from Tiago] and also ended up working with that concept, that is, the fraction that represents the unit.*

Next, Marisa recalled that it was the student that she observed (Berta) who introduced in the discussion the notion of equivalent fractions, albeit she did not do that in her written solution. Besides the representation $\frac{2}{3}$ (the picture was divided in three parts, and two

were shaded) that was recorded by most students, Berta indicated $\frac{4}{6}$. The following dialogue recorded on video was observed:

Berta:	*In question a) I know another.*
Teacher:	*You know? Say it.*
Berta:	*Four sixths.*
Teacher:	*Four sixths . . . The unit divided in three parts and we have two of those parts painted. Berta says that this figure may be represented by four sixths. Explain why four sixths.*
Berta:	*because if we divided the picture at the middle...*
Teacher:	*At the middle, how?*
Berta:	*Horizontally... [figure 2] We get four painted parts which is the numerator and six parts in which the picture is divided.*

Figure 2. Berta's justification for the representation $\frac{4}{6}$



Inês emphasized the way this student justified her reasoning:

> *Berta represented the given $\frac{4}{6}$, from $\frac{2}{3}$ she moved to $\frac{4}{6}$, I think that she really explained in a very simple way, put a line at the middle and the other saw that indeed... Very well...*

Tânia regarded the way that Louise took the students' interventions to address the equivalence of fractions and the concept of unit as vey positive. However, she concluded that the aim of the lesson – comparing fractions with the generalization of the rules for comparing fractions with the same numerator and with the same denominator – was not achieved with this task:

> *We didn't think about it but it emerged from a student and I believe Luísa did very well. It was the one that... And Luísa got there a way to introduce the fraction that is equal to unit, also asking the students for examples. Although it was not our purpose, I think the lesson... The concept [equivalent fractions] emerged and she took advantage. I think that what we thought for question "1", which was comparing fractions, it was everything [misplaced]... For fraction comparison, we have seen that this [task] doesn't work. For me, after seeing this, it is not with this task that we can reach the aim of comparing fractions . . . So we have to make another task or other work completely different to compare fractions. For equivalent fractions I think that there is much work that has already done and for the fractions that are equal to the unit there are many concepts that have been tackled.*

During the post lesson reflection, the group of teachers was strongly united and committed to the planning done, and made a quite critical and assertive analysis the observed lesson, focusing on students' learning.

Individual and collective reflections

The work done during the lesson study sessions was based on collaboration and sharing in a climate of open communication between all participants with a high value on collective discussion. The relationship between teachers and IE members become quite friendly and everyone participated collaboratively, exposing their experiences, questions, and reflections. The interviews took place in this environment where the teachers were invited to reflect on the work developed in eight working sessions and about their learning.

Luísa highlighted her learning and the structure of a lesson and the role of the students. She also indicated that she had found on the internet several papers (including some written by us) on rational numbers and read them:

> *I don't think it was only in the topic, was even my stance in the class, to try that the students have a more active role in managing the class, not just me at the center. To try that they participate more, give them a better chance of response. That's one of the things I learned more, actually. This is mainly because I have been doing several readings of documents that you published within this area and found the discussions that you had with students very interesting, and I learned a lot from that.*

Luísa appreciated the dynamics of the research lesson and the communication style that we promoted for discussion along the lesson study sessions. She recognized its potential and indicated in the interview (and this was quite surprising to us) that she had done some research regarding our papers about the teaching and learning of rational numbers. In the final reflection, Francisca and Maria also said that they had done some research about our work and Irene mentioned that she had already participated in an open seminar carried out at the university by members of our team. This shows the teachers' empathy with our team and their interest in our research work and in retrospect we wonder if this was a reason why they agreed to participate in the lesson study.

The follow-up sessions

The work and discussions of the lesson study lasted for four additional sessions where the five teachers carried out activities in their classes and presented aspects of the work done and their reflections to the group. In these sessions there was opportunity to systematize and review many of the discussions and aspects of practice identified in the initial sessions. Questioned about its importance in their development, the teachers indicated that they appreciated these sessions as an additional opportunity to put into practice the issues discussed in the work sessions and noticed during the research lesson:

> *I think so [they are important]. I think it's a logical path. Because it was what you've said a while ago, this was not only rational numbers. We had rational numbers as a backstage and we were working more things, and what we've learned in the research lesson we applied now. We saw possible difficulties; each one chose the most appropriate expressions for their classes in order to verify something. So, at the end we applied what I think is essential and we all learned that it was the whole class discussion. The discussion with our students is the central point of all this. So, when we ask students to do exercises and we are observing, sometimes we don't make the final part which is: let's see how it is; if everybody is understanding it and sharing what they learned or did not learn, and collaborating with each other towards learning. I thought that it has logic and is the same... When we teach geometry, we will also apply it. Isn't that so? (Luísa)*

The teachers valued the issues addressed in the lesson study, such as the nature of the tasks and the different levels of challenge, the anticipation of the students' difficulties, the importance of reasoning, the attention to the interesting strategies of students. They also highlight the value of collective discussions as learning opportunity. However, they seem to relativize the lesson study regarding the learning about the topic, assuming that they still have a lot to learn about other topics that are creating strong problems to teachers in the implementation of the current mathematics syllabus, such as geometry.

At the end of the lesson study, we were quite surprised with the very emphatic way that the teachers praised the collaborative work carried out by the group, as this had never been discussed in the sessions. Francisca and Maria, in their reflections, speak about this:

> *For me it was very positive... Because... we worked together, we shared information... And the work between teachers is extremely important, often one feels alone. Isn't that so? We are working and we only think about that one... And we forget that this is a sharing job and that's it... I thought that the important [thing] was just that. We open ourselves to the others. We were not afraid of... Because, sometimes there are people who are afraid to show their weaknesses. And I found sharing very useful, that is, to work as a group, that's it. I think it's essential because the difficulties. Sometimes we do not see that something is going to be a difficulty and it is.*

> *Exactly what I just said. It improved concerning the group because we were three tenured teachers, here at this school, for many years. There are many years that we don't join together anymore, because we already know the working methods of each other . . . And I think that this lesson study provided that contact also with new colleagues. Look, there we had two people [teachers] that we didn't know, and whose way of working we didn't know. And, yesterday, when we did that preparation of a lesson, so, I got with... We were two old women with a new one and I like this contact. I'm being sincere with you. (Maria, Interview)*

Summary

The teachers began their participation in the lesson study suspiciously but, as they worked on mathematical tasks and analyzed the students' solutions, with reference to their own experience, they became strongly involved. The carefully planned sessions and the environment of openly questioning the issues, the respect for everyone's ideas, the argumentation supported with classroom data and research results yielded an atmosphere of interest and trust for a collaborative setting.

In this group, three teachers had been in this school for more than ten years and knew each other well, although they did not work together very closely. Two teachers had just arrived at the school. The lesson study promoted a new dynamic of work to the veteran teachers at the school and it was an important factor to include the new teachers. The teachers valued the opportunity to work together with their colleagues and to meet and share ideas. That is, the lesson study led to the constitution of a working group with all of the active grade 5-6 teachers of this school.

A lesson study at Grade 3

The lesson study at grade 3 begun with seven teachers, Elsa, Irina, Manuela, Matilde (teaching grade 3), Catarina, Miguel, and Silvia (teaching grade 2), who were invited by the principal with the advice of the coordinator of primary education. However, this group was very unstable, with several teachers withdrawing along the way. After a few sessions there were only three teachers remaining. One of these teachers was very enthusiastic but the other two showed very little involvement in the sessions, leading us to believe that the process would not be completed or would be just a caricature of a lesson study. However, at some point there was a change, the group become more cohesive, and we ended up with what we consider a fruitful lesson study.

The group for the lesson study

The constitution of the group proved to be very problematic. Session 1 was attended by six of the seven teachers invited to participate in the lesson study. We presented the process to the teachers who had no idea about this professional development model. We presented several examples of lesson studies from Japan, where it was originated, and from the USA, where it is widely used. The session was dynamic as some teachers were curious to understand what was going to happen. Irina and Manuela were the most active, raising questions such as: “Is it just a class observed? Can we do the same in another class? Is it for teaching a new subject? Is the lesson planned by the group? Will the teachers circulate around the room? Will we work with you? Will everything be decided together?” We answered these questions presenting examples from our previous experience. However, the remaining teachers made very few interventions. We quickly realized that this set of teachers did not constitute a natural working group and that it was necessary to create an environment of trust, where all of them could feel comfortable in sharing ideas and in exposing difficulties.

At the beginning of session 2 there were only three teachers. Miguel, a teacher, with a short-term contract, informed us that he was not going to continue to participate since he would leave the school soon and he left the session. The two teachers that were present, Irina and Elsa, reported that two of the four remaining teachers would not participate in the session due to personal reasons. After waiting for more than a half an hour, we realized that the two missing teachers would not come and the session was adjourned.

In session 3 we were informed that two teachers had given up the lesson study: Silvia because she was not teaching grade 3 and Catarina due to health problems. Thus, in this session the group had cut down to four teachers. Finally, at session 6 we were informed of

the withdrawal of Matilde (with no reason given). In this way, the large group of seven teachers became a small group of just three teachers – Irina, Manuela and Elsa. Irina was much more knowledgeable of mathematics than her colleagues and she was very involved in the activity carried out at the sessions. She very quickly became the informal leader.

Questioned why so many people had given up their participation in this lesson study, Elsa, in the focus interview, referred to lack of motivation among Portuguese teachers, which she related to current educational policies:

> *People [teachers] are very unmotivated, indeed . . . We used to have mandatory teacher training and we engaged ourselves. Now, we do not know whether it is necessary or not [to take courses]... Mostly, I think that people are very unmotivated in schools. That's it [the reason that led to the withdrawal of the four teachers].*

This group of seven teachers was quite heterogeneous and artificial, as it was created especially for this study. The teachers did not know what a lesson study was. We assumed that they would be well informed by the school administration, after the initial meeting in the school, but that did not really happen. Several teachers that attended the first session may have realized that lesson study would require a lot of work and, perhaps, not very interesting work for them and decided not to continue.

Besides the issue of informing the teachers about the aims and style of work of a lesson study there was also the issue the constitution of the group. The teachers had no joint working habits and there was no official group leader. With a clear leader from the beginning, maybe the teachers who could not attend a session may have notified this person and, if necessary, that session could have been rescheduled. The lack of a clear leadership in the first sessions may have also influenced the lack of commitment of some teachers to the group.

Different levels of involvement

Another problematic feature was the very different levels of involvement of the three teachers who completed the lesson study. Irina was always the most engaged person. Manuela took notes and tried to understand the work that was undertaken. However, she rarely participated in the discussions. Elsa, in many sessions, showed very little involvement.

After the research lesson, Manuela explained that she did not feel comfortable with mathematics and reported that in several sessions she was unmotivated because she had difficulty in following the solution of the mathematical tasks:

> *Look!... For me, I think, quite honestly, what was good was... Bringing us closer to something concrete. And, for me, as I'm not from this area [mathematics and science]... For me mathematics [is very difficult], there is [I have] some resistance regarding mathematics. For me, some sessions were, for me, a little bit more monotonous... And I felt I couldn't be... So up ahead, so safe... [as my colleagues] and to follow... The rhythm and what was happening. I felt that. And so, I felt that some sessions were monotonous... And when there is some monotony I feel like I'm not there... (Manuela, Interview)*

Manuela indicated that she never felt at ease to raise questions in order to discuss her troubles of difficulties during the first sessions of the lesson study. In her view, asking question "could be not appropriate". However, she was working at home to overcome her difficulties. She also reports that at some point she began to get more involved with what she was learning about the topic and the enthusiasm that the preparation of the upcoming lesson brought to her:

> *Honestly, the closer we got... To the class itself... isn't it? As more I saw things already put into practice... More I went enjoying it, and also because at that point I already was more comfortable on the topic. Therefore, it turned out to be a growing up process. (Manuela, Interview)*

According to Manuela, her involvement and motivation for the lesson study were influenced by several factors. Initially, she felt insecure in her mathematical knowledge about rational numbers, and she was still not familiar with the topic to teach, yet very far in her planning. The second phase arose as the research lesson got nearer. At this point, she began to feel more challenged, especially because she had already started to teach rational numbers and yet she felt more comfortable in this topic.

Elsa also showed little enthusiasm in the initial phase of the lesson study and was frequently absent minded. When the effective preparation of the lesson for observation began, she participated more. At the end of the lesson study, she pointed out two reasons for her lack of initial involvement: the detailed work done on each task and the fact that chosen topic would only be taught much later.

As a very active person with strong inclination for mathematics, Irina was always the most participative teacher in the group. In the focus interview, she indicated her embarrassment at the lack of involvement and participation of her colleagues, especially when Marisa from the IE team asked a question and they said nothing.

> *I felt strange. I know I talk a lot, but [Manuela] confused me. Because there was sometimes an awkward silence, wasn't there? Sometimes I thought: "now I won't speak" but then I had trouble [in doing so] . . . I think (and now I say it) that from the moment they began to take a different stance this [the lesson study] begun to be more fun and it [the climate] relaxed. . . At the beginning, maybe because [Elsa] missed the first session and did not know what this was, you were a little [absent]... And maybe when you also began to pull a little more that made all of us to be talking more and this got more natural. (Irina, Focus Interview)*

For us, it was a very positive surprise how, at session 5, when we began the actual framing of the plan for research lesson, the whole dynamic of the group changed, and not just Irina, but also Elsa and Manuela became active participants, contributing to the aims of the lesson study.

Tension regarding the lesson to observe and becoming a different group

In addition to the different levels of involvement, we realized that in the first five sessions there was a strong tension in the group regarding who would teach the research lesson. Irina explains it quite eloquently in the focus interview:

> *On the first day, when I walked out of the room, a colleague told me "you're going to have to teach the lesson", and I said "Me? What nonsense. Why not someone else?" . . . So, the tension began there: who is the person who will be in the room with so many people observing? It was a strong tension. [I asked myself] how will I have all those people in the room, the kids behave so badly . . . [Later] I realized that nobody [Elsa or Manuela] would take a step . . . I said several times, I don't think it should be me . . . I think that the tension began to dissipate when I said "I don't mind it being me". Then I think things calmed down a bit. Calmed down? No, it was a relief. I knew it would probably come to me.*

Irina has training as a primary and middle school mathematics teacher. She showed a lot of confidence and knowledge and from session 1, her colleagues suggested that she should teach the research lesson. She was comfortable with mathematics and she thought that it should be one of her colleagues to teach the lesson, as a learning experience. However, Irina felt the pressure that the other teachers put on and, when this issue had to be finally decided, in session 5, she volunteered. She recognized that with this decision the tension disappeared and the relationship within the group improved substantially.

The group acquired a new dynamic in preparing the research lesson addressing addition of rational numbers represented on number lines. As it occurred with the grade 5 lesson study, the preparation for the lesson involved a joint analysis of the new official curriculum documents, which were new for the teachers since it was just being implemented for the first time. It included also working on mathematical tasks to figure out possible ways of addressing the notions indicated in the curriculum as well as the analysis of students' responses. There was also a diagnostic test of students' previous knowledge based on a set of tasks jointly selected and adapted in a session with the students' responses analyzed in the subsequent session. All this work was carried out in a collaborative way, with division of tasks and negotiation of schedules and responsibilities. Making a general assessment of what important previous knowledge should be taken into account, selecting tasks, and, analyzing the students' responses proved to be a very interesting and fruitful activity that drew the teachers' involvement.

When the tension regarding the decision of who would teach the research lesson disappeared, the discussions aroused a great interest from the teachers. This lesson turned out to be a great satisfaction both for Irina, who taught it, and for her colleagues. Irina indicated that she felt very nervous about the preparation of the lesson, with the responsibility of the teaching. When the lesson was over, she indicated that she enjoyed the experience. Elsa considered that "it went very well" and she enjoyed observing the students. Manuela, in the individual interview, expressed herself very enthusiastically, indicating that the lesson was an important experience for her:

> *I enjoyed it so much. For me it was a learning experience . . . I think it was a benefit for me to attend Irina's lesson, no doubt! . . . Because I think that the security and the way she regards mathematics… I was listening to her… And I think that I have something to learn from Irina . . . I've learned much more than if perhaps I was doing the lesson.*

The follow-up sessions

Besides the reflection on the research lesson, there were four additional sessions for preparing and reflecting on new lessons on other aspects of rational numbers. Questioned about these sessions, Manuela and Elsa were very positive. Manuela said that it was a good time to consolidate the knowledge about the topic and Elsa highlighted that, at this stage, they were much more familiar with this topic. This phase was also marked by a stronger collaboration among the teachers. In fact, as they were planning these follow-up lessons, Manuela and Elsa decided to choose the topic which they were to teach and apply it to the lesson in order to "ease" Irina's responsibilities, recognizing that she had been very overwhelmed during the former part of the lesson study. Irina, herself, considered in

her written reflection that “after the reflection on the research lesson the tension disappeared completely and the group changed a lot. I think that the lesson was finally demystified and all of them understood that any of them could have taught it”.

So, after the research lesson, the teachers were much more involved in the sessions and more friendly. In the final session we reflected on the whole process and the three teachers spoke spontaneously about what they had thought of the lesson study, about what they had enjoyed and also about what they had thought that did not go so well.

Summary

There were several problems in this lesson study. Concerning the initial group of seven participants, the high number of withdrawals was a very disturbing feature of this lesson study. We realized that the teachers need to be informed from the very beginning about what a lesson study is, so that they can decide if they want to be involved or not. We also realized that clearer leadership among the participating teachers would be helpful, to reinforce the commitment of the participants and deal with practical issues.

There were also problematic issues regarding the three teachers that completed the lesson study, as the very different levels of involvement of the teachers in the first phase and the tension regarding the decision about would teach the research lesson. We realized that one of the teachers feared exposing her difficulties with the mathematical content and another had little interest in the preparation that seemed to her to move very slowly. The fact that the content that they were going to teach was to be taught much later in the school year seemed to influence the involvement and the dynamics of the group, as the teachers had some difficulty seeing what really the goal was. In addition, the group dynamic was constrained until a teacher was chosen to teach the lesson. The first radical change occurred with the decision about who was going to teach the research lesson and this was consolidated in the post-lesson reflection and the individual interviews that we carried out at that point. When the factors that created distance and tension were overcome, the atmosphere of the group changed in a noticeable way. The collective post-lesson reflection and the individual interviews improved the relationship of the participating teachers with us and the final focus interview was carried out in a very friendly and participative atmosphere.

Conclusion

These two cases show the potential of this professional development setting to foster teachers' knowledge and practice and also some of the issues that may arise during a lesson study. Organizational issues arose in the two groups. The involvement of the principal and the preparatory meetings was not enough to provide the teachers the information about the purpose and features of the activity. Some teachers withdrew from the lesson study when they realized that it would require a rather different involvement of a usual professional development activity. We assumed that the groups of teachers would organize themselves and this was true for the grade 5 teachers who had a coordinator appointed by the principal but not for the grade 3 teachers in which informal leadership took some time to emerge. The absence of a teacher-leader (Perry & Lewis, 2009) created difficulties for the work of the group. Also, the decision about who would teach the research lesson was very problematic in both groups. Portuguese teachers are very sensitive about evaluations and observations of their classes, and so this is not surprising. This will probably remain a problematic issue for lesson studies as long as the current concerns with evaluation prevail among teachers.

In these two lesson studies, the detailed preparation of the research lesson was an opportunity to discuss in depth many of the issues that teachers have to consider in their professional activity. The review of curriculum documents and research-based articles was important to set the stage for the subsequent work. The value of focusing on mathematical tasks and on the students' reasoning in working on those tasks was quite apparent. As Lewis et al. (2013) have also reported, we created a lot of opportunities for teachers to get involved in doing mathematics themselves. We also provided many occasions to discuss didactical issues such as the features that can make tasks simple exercises or more engaging problems or explorations (as in Cajkler et al., 2014; Lewis et al., 2013), as well as features of reasoning processes such as justification and generalization (Lannin, Ellis & Elliot, 2011). Anticipating possible difficulties of students and looking at what they actually do in the classroom are key features of lesson studies (Alston, Pedrick, Morris & Basu, 2011) that were very effective in leading the teachers to reflect and consider changes in their classroom practice. The teachers become more attentive to students' reasoning processes, especially to generalizations and justifications. They could realize the potential of exploratory activity, combining students' work in significant tasks with whole class discussions. This was achieved by looking at examples of students' work, but also through their undertaking of the diagnostic study, the

observation and discussion of the research lesson, and by their lessons and reflection in the follow-up stage.

This work produced a quick strong involvement of the grade 5 teachers but took more time with the grade 3 teachers due to their more complex relationship with mathematics. All teachers that concluded the lesson study were quite positive about what they learned regarding students' strategies and difficulties. They recognized that they learnt much about the teaching and learning of the topics they had opportunity to work on, and they developed their knowledge about the potential of different kinds of tasks, about students' reasoning processes, and also about ways of conducting classroom work in an exploratory framework.

In both groups of teachers there was, in the end, a relationship of confidence amongst the participants themselves and with the members of our team. One of the aspects that they most emphasized in their reflections was the creation of a collaborative culture. A critical point was the observation and reflection of the lesson – the lesson that created so many fears became something that was interesting to observe and to reflect upon. Other important elements of these two lesson studies were the follow-up sessions that provided the teachers the opportunity to immediately trial on their classes the ideas that were discussed in the lesson study sessions. In the individual interviews, made right after the research lesson, it was noticeable that all teachers spoke with pleasure of their experiences in the lesson study, showing that their initial reservations gave place to a relation of confidence and trust with the other participants and the members of the IE team.

We conducted these two lessons studies as a small collective investigation by the group of participants in their own practice. We began by framing a research question, then we carried out some systematic work to prepare an experiment (the research lesson), next we collected and analyzed the data on it, and tried to apply the findings to other situations. We did so by combining teachers' experiential knowledge (from past experience and from the experience in the lesson study) with research knowledge that we introduced in the activities and the discussions. We strove to do this in an exploratory and collaborative environment. These were critical design factors (Loucks-Horsley, Hewson, Love & Stiles, 1998) for the success of lesson study that our experience suggested should be taken into account to achieve positive results in terms of teachers' learning in the Portuguese context.

References

Alston, A.S., Pedrick, L., Morris, K.P., & Basu, R. (2011). Lesson study as a tool for developing teachers' close attention to students' mathematical thinking. In L. C. Hart, A. Alston & A. Murata (Eds.), *Lesson study, research and practice in mathematics education* (pp. 135-151). Dordrecht: Springer.

Artigue, M., & Blomhøj, M. (2013). Conceptualizing inquiry-based education in mathematics. *ZDM Mathematics Education, 45*, 797–810.

Bishop, A., & Goffree, F. (1986). Classroom organization and dynamics. In B. Christiansen, A. G. Howson & M. Otte (Eds.), *Perspectives on mathematics education* (pp. 309-365). Dordrecht: D. Reidel.

Bruner, J. (1991). The narrative construction of reality. *Critical Inquiry*, *18*, 1-21.

Cajkler, W., Wood, P., Norton, J., & Pedder, D. (2014). Lesson study as a vehicle for collaborative teacher learning in a secondary school. *Professional Development in Education, 40*(4), 511-529.

Gravemeijer, K. (2005). What makes mathematics so difficult, and what can we do about it? In L. Santos, A. P. Canavarro & J. Brocardo (Eds.), *Educação matemática: Caminhos e encruzilhadas* (pp. 83-101). Lisboa: APM.

Huang, R., Su, H., & Xu, S. (2014). Developing teachers' and teaching researchers' professional competence in mathematics through Chinese Lesson Study. *ZDM—The International Journal on Mathematics Education*, *46*(2), 239-251

Lewis, J., Fischman, D., Riggs, I., & Wasserman, K. (2013). *The Mathematics Enthusiast, 10*(3), 583-620.

Lewis, C., Perry, R., & Hurd, J. (2009). Improving mathematics instruction through lesson study: A theoretical model and North American case. *Journal of Mathematics Teacher Education*, *12*, 285-304.

Lannin, J., Ellis, A.B., & Elliot, R. (2011). *Developing essential understanding of mathematical reasoning: Pre-K-Grade 8*. Reston, VA: NCTM.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K.E. (1998). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Murata, A. (2011). Conceptual overview of lesson study. In L. Hart, A. Alston, & A. Murata (Eds.), *Lesson study research and practice in mathematics education* (pp. 1-12). Dordrecht: Springer.

NCTM (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

Perry, R., & Lewis, C. (2009). What is successful adaptation of lesson study in the US? *Journal Educational Change, 10*(4), 365-391.

Ponte, J.P. (2005). Gestão curricular em Matemática. In GTI (Ed.), *O professor e o desenvolvimento curricular* (pp. 11-34). Lisboa: APM.

Ponte, J.P., Baptista, M., Velez, I., & Costa, E. (2012). Aprendizagens profissionais dos professores através dos estudos de aula. *Perspectivas da Educação Matemática, 5*, 7-24.

Ponte, J.P., Mata-Pereira, J., Henriques, A.C., & Quaresma, M. (2013). Designing and using exploratory tasks. In C. Margolinas (Ed.), *Task Design in Mathematics Education: Proceedings of ICMI Study 22* (pp. 493-501). Oxford.

Riessman, C. K. (1993). *Narrative analysis*. Newbury Park: Sage.

Skovsmose, O. (2001). Landscapes of investigation. *ZDM, 33*(4), 123-132.

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Retrieved from: http://www.educationaldesigner.org/ed/volume3/issue11/article45/