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Negotiating the content and the teaching of statistics: Two complementary processes in teachers' professional development

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This study builds on Wenger's (1998) notion of meaning as the essence of a practice and the process of negotiation of meaning as determinant in the development of a practice. Following an emerging community of 11 secondary mathematics teachers, I aim at exploring the interactions between two dominant processes in teachers' work, the negotiation of the statistical content and the negotiation of the teaching of statistics. The results indicate that the two processes act complementarily in the formation of the practice of the community and consequently in the professional development of the teachers. Evidence of how the one provides feedback and meaning to the other is also illustrated and discussed.

Keywords: Community of practice, mathematics teachers, teaching and learning of statistics.

Introduction

The development of teacher education programs that aim to support teachers to promote statistical inquiry in their classroom, is gaining an increasing attention the last years in statistics education community. This current discourse emphasizes the importance of offering teachers opportunities to experience as learners statistical investigations (Makar & Fielding-Wells, 2011), and nominates the significance of teachers' engagement with inquiry in the teaching (Shaughnessy, 2014). A further approach suggests combining experiences in teacher education, namely as learners and as teachers, and provide evidence that this combination can help teachers not only to strengthen their statistical content knowledge but also to be able to transfer their understanding to the classroom (Heaton & Mickelson, 2002). Although the complementarity of teachers' experiences as both learners and teachers seems to be crucial in teacher's professional development, we still know very little on how these two types of experience interact and provide feedback to one another.

In this study I explore the interplay between the process of negotiating the content of statistics (NCS) and the process of negotiating the teaching of statistics (NTS) in the professional development of teachers. Particularly, I followed a group of 11 secondary mathematics teachers who worked collaboratively in an emerging Community of Practice (CoP) (Wenger, 1998) to develop the statistics teaching practice. During their work in this community, the teachers had the opportunity to engage in tasks that promote negotiation of meaning in both the content and the teaching of statistics, and so they participated as both teachers and learners. The research question that guides this exploration is the following:

How do negotiation of the content of statistics and negotiation of the teaching of statistics interact and provide meaning to each other in the context of a Community of Practice?

Theoretical perspectives

In this study, I view the teaching of statistics from a *statistical thinking* point of view (Wild & Pfannkuch, 1999) which sets inquiry at the core of statistical teaching and learning and highlights both the specificities and the complementarity between statistics, probability and mathematics. I focus

on three dimensions related to statistics teaching practice. The first dimension is the *learning potentials* which refer to particular skills, abilities and knowledge that are connected to the statistical activity, e.g. that students are expected to understand and deepen in the fundamental statistical ideas (Burrill & Biehler, 2011) or that they need to be able to use and evaluate appropriate statistical tools and methods in order to analyze data (e.g. Franklin et.al., 2005). The second dimension is the *features*, namely instructional tools and strategies that seem to be crucial in supporting students to achieve the defined *learning potentials*. Examples of features are students' engagement in statistical investigations (MacGillivray & Pereira-Mendoza, 2011) or the use of dynamic software tools that support data explorations (Ben-Zvi, 2006). The third dimension is *resources*. The variety of the resources that are brought into the teaching of statistics constitutes a dynamic ground where teachers can build and form their practice. In my view of resources I adopt Adler's (2000) conceptualization which extends beyond material resources (e.g. software tools, physical objects, media extracts, real data sets) to include human resources (e.g. previous experiences, collaboration with colleagues, knowledge about concepts and procedures) and cultural resources (e.g. time, classroom habits).

In my view to practice, I use the lens of the social theory of learning (Wenger, 1998) which theorizes learning in practice through four components: *meaning* (the way we experience our life and the world as meaningful), *practice* (shared historical and social resources and actions), *community* (social configurations to which we belong) and *identity* (personal histories of becoming). In the social theory of learning, practice is about both action and interpretation of the action, and meaning is the essence of a practice and it is situated in the process of *negotiation of meaning*. In this study, I acknowledge two types of meaning that is negotiated in the CoP, the meaning related to the content of statistics where the teachers participate as learners in the negotiation, and the meaning related to the teaching of statistics where the teachers participate as teachers in the negotiation. The study of the interaction between the process of NCS and the process of NTS aims to get insight on how NCS can provide meaning for NTS and vice versa. Especially in the case of teaching statistics where the mathematics teachers are challenged with a content that they are not familiar with (Hannigan et.al., 2013) and which contains epistemological differences from the mathematics content they teach (Moore & Cobb, 2000), such insights could be rather helpful for the research in statistics teachers' professional development.

Methodology

To achieve my research goal I followed an exploratory case study methodology (Yin, 2003), where the case was a group of 11 secondary school mathematics teachers, 5 practicing (Akis, Dinos, Kimon, Lidea, Marcos) with 8-30 years of teaching experience and 6 prospective (Athina, Chloe, Eva, Lia, Ria, Sofi). All teachers were mathematics graduates and also graduates or senior students in a Master's program in Mathematics Education with no particular familiarity with the teaching and learning of statistics and with a varied background in statistics. This group was gathered in a voluntary basis and worked collectively for two years (2012-2013 and 2013-2014 academic years) in a regular base (about 2 meetings per month that lasted approximately two and a half hours each). Two researchers were also participants (the author-R1 and the supervisor of the study-R2) encouraging the active participation of the teachers, providing various resources, finalizing each meeting's agenda and challenging teachers to reflect on their experiences. The main agenda of the meetings was formed around a cyclic route of: (a) inquiring the content of statistics, (b) designing for their classroom (c)

implementing the designed tasks in their classroom and (d) reflecting on their practice. I considered this group as an emerging Community of Practice (Wenger, 1998) by encouraging the development of mutual engagement, joint enterprise and shared repertoire. This paper is based on the data of a full cycle (inquire the content, design teaching, teach the planning lesson and reflect on it) which covered 10 of the total of 12 meetings in the first academic year.

All meetings were audio and video recorded and the group discussions were fully transcribed. Semi-structured individual interviews at the beginning and at the end of the study were also conducted. Another source of data was teachers' journals regarding issues they considered as central in each meeting. Although these reports were not a complete source of data, they often constituted a useful source of triangulation in order to corroborate the study's findings.

The analysis of the data was based on a grounded theory perspective using the ATLAS.ti software. During the coding process I used as unit of analysis the task that the teachers were engaged in. In each task I distinguished NCS and NTS parts in which I assigned *features*, *learning potentials* and *resources* that were visible in teachers' discussions. In Table 1 I present an example of the process we followed. Last, in a second level I focused on identifying how the negotiation of each type of meaning was mobilized as well as exploring interactions among the negotiation of the two types.

Negotiating the content (extract from the 2nd meeting)	Features	Learning Potentials	Resources
<p>Akis: Now, I couldn't understand this very well. As Fischbein mentioned in his article it is the concept of proportionality behind this. He said that we still use proportionality in order to make a conclusion instead of using the Law of Large Numbers.</p> <p>Lidea: An what is this Law of Large Numbers?</p> <p>Ria: It is when something is repeated many times, then it approaches the theoretical probability.</p> <p>Marcos: It is what we say to estimate the probability through the relative frequency. We then consider the probability as the number of the favorable cases to the total number of the cases, when we repeat this many times and the number of times tends to infinity etc. So let me explain what we have here. You have a small and a big hospital and you get a sample from each one. I think that this has to do with the variability, I mean practically it is like you have a small and a big sample, which one do you expect to be more accurate? More representative with regard to the theoretical probability. It is the small sample or the big sample? It is the big. This is the case with the big hospital, because in the big hospital the births will be closer to the mean value, while in the small hospital you will have large variability.</p> <p>Lidea: But I still can get why the small one is the right answer in this task?</p> <p>Marcos: Wait a moment. What is the question in this task? It asks in which hospital it is more likely to have more such days.</p> <p>Akis: Is it possible that I may didn't translate it correctly?</p> <p>Lidea: No Akis, it is absolutely correct. I translated it with exactly the same way. But I can't understand why. When he says 'such days'...</p> <p>Dinos: (talking to R1) Do you remember the example you had discussed with us (he means sometime in the past). The one that says that the half of the newborn children are boys. This is very similar and more comprehensible. Maybe you could show us this one.</p> <p>(R1 goes to the computer and projects the task mentioned by Dinos, they continued to discuss the task using the projector and the blackboard)</p>	<p>Engagement with an inquiring task</p> <p>Plenary discussions and negotiations (as experienced by the teachers)</p>	<p>Connect to probability ideas</p> <p>Deepen on sampling notions</p> <p>Appreciate variability</p>	<p>Educational research (Fischbein's article)</p> <p>Mathematical tools (proportionality, Law of Large Numbers, theoretical probability)</p> <p>Statistical tools (relative frequency, sample, mean value, variability)</p> <p>Cultural tools (language)</p> <p>Human (collective experiences, difficulties)</p> <p>Material (computer, projector, blackboard)</p>

Table 1: Example of the data analysis where the teachers were discussing the 5th problem presented on Fischbein & Schnarch's article (Fischbein & Schnarch, 1997)

Results

In Figure 1 I present the various tasks that the teachers were engaged in during the 10 meetings. As we can see, there were tasks oriented to encourage negotiations in the content of statistics (e.g. exploration of statistical tasks/situations), tasks that aimed at negotiating the teaching of statistics (e.g. design for the classroom, reflection on the teaching) and tasks that had the potentiality to immobilize negotiations in both types of meaning. However, as we can see in Figure 2 the realized negotiations indicate that the interaction between NCS and NTS was not only a function of the nature

of the task. This is especially obvious in the case of the design for the classroom tasks, where a quite large part of teachers' discussion was related to NCS.

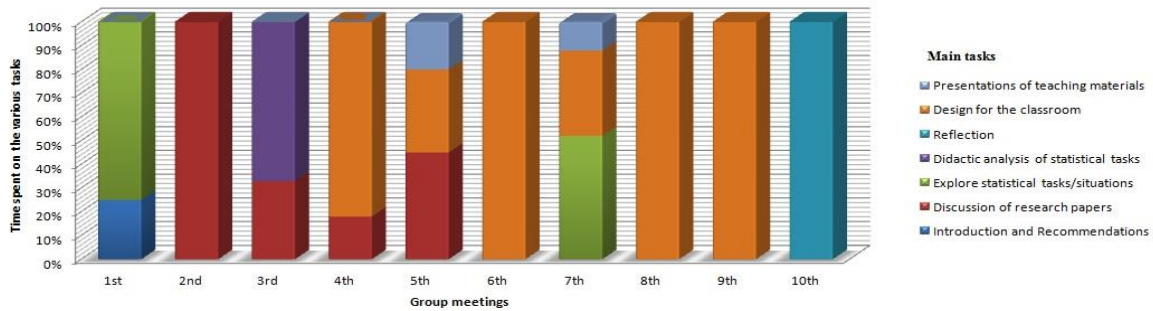


Figure 1: General description of the meetings agenda

How NCS provides meaning to NTS

The analysis of the data showed that NCS was mobilized by the teachers' need to understand better or deepen in a statistical concept or process. In the extract presented in Table 1 above, the teachers were discussing students' false intuitions with regard to the effect of sample size while Akis' intervention mobilized a negotiation of meaning related to sample notions and the Law of Large Numbers. This episode was expanded and lasted for about 10 minutes during which the teachers together with R1 exchanged arguments and utilized various resources that aimed to deepen their understandings around these notions. This discussion helped teachers not only to deepen their content knowledge but also to negotiate new difficulties that they had (making connections with particular knowledge and abilities required to gain meaning, namely the learning potentials) and means that helped them to overcome these difficulties (namely the features that can facilitate these learning potentials). In other words, they had the opportunity to incorporate their NCS experience into their teaching practice. Akis notes in his meeting report are indicative of how NCS provided meaning for the teaching practice: "What I observed is that our beliefs and our attitudes towards probability and statistics are very close to those of students, I mean we are guided by an intuitive way of thinking. If we want our students to adopt a more inquiring stance, we first need to give them appropriate tools to overcome their intuitions. I think that the way we discussed in the meeting, revealing our misconceptions and resolving them could be a good model for our teaching".

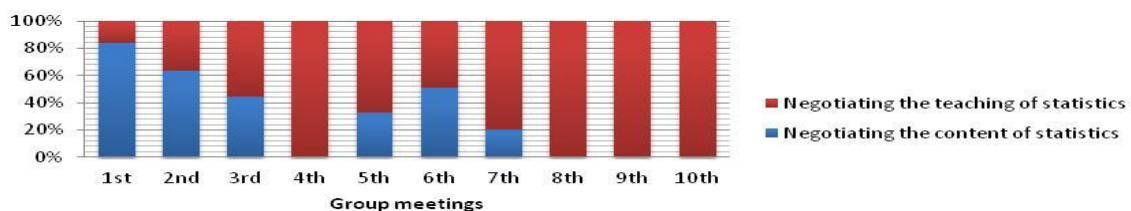


Figure 2: Alternations in the content of negotiation in the various meetings

Moreover, NCS was also mobilized by teachers' need to gain experiences with data. This was the case for example in the 6th meeting, where the group conducted a pilot study for an experiment that was designed for the students by a team of five teachers. Particularly, in this experiment the students were supposed to investigate if listening to music affects their ability to recall words. The teachers designed the experiment and before they implemented it in the classroom they collected data inside the group, explored the data, made conclusions and thought of possible modifications in the

experiment's design. In this sense the NCS helped teachers to acquire experience and confidence regarding the implementation of the designed activity. The words of Dinos in his final interview are characteristic: "this interaction gives you the impression that this (he means the task) will be considered by many couples of eyes, by many views. I mean especially in statistics where you can never acknowledge all the possible parameters,... it is not that you will learn something new, it is that it helps to illuminate other dimensions that you may have neglected at first".

Furthermore, in many cases the teachers transferred directly their experience as learners to their teaching practice. For instance, in the 6th meeting Dinos used an example to help his colleagues to understand the notion of the standard deviation in the estimation of a probability. Later in the discussion, Dinos suggested using the same example in the classroom and the others responded:

Sofi: So you suggest using the same example with the students. I like it. Actually it helped me to understand so it would be also helpful for students to understand.

Athina/Chloe: Yes, I agree too.

Last, as can be seen in the examples discussed above, it is also the general context of their enterprise, namely the community of statistics teaching practice, that mobilized them to analyze their NCS experience in terms of identifying learning potentials that could be supported in the classroom, features that could support these learning potentials and resources that could facilitate students in the learning process.

How NTS provides meaning to NCS

Apart from the nature of the task, NTS was mainly mobilized due to a question posed by one of the researchers, such as "Would you use such a task in your classroom and if yes how?" or "What do you think a student can gain from the experience of such a task?". Such questions encouraged teachers to extend their experience as learners to start a negotiation of meaning around the teaching and learning. The extract below is from the 3rd meeting when teachers discussed a statistical task and illustrates how such NTS was mobilized.

R1: What difficulties can someone face in the classroom with this task? Would you try to implement such a task? If yes, then how and with what goal?

Kimon: I could try it with 12th Grade students not with younger ones.

Dinos: I could do this with young students as well, with 8th Grade students for example.

Lia: I agree with Dinos. I think this would be useful in the formation of their attitudes towards probabilistic ideas. In 12th Grade level they have already formed quite formal conceptions.

Dinos: But the point is what modifications we can do.

This discussion for which the starting point was the question posed by R1, continued for about 30 minutes during which the teachers exchanged views and suggestions, referred to specific learning potentials, discussed potential features that could serve their goals and utilized or suggested resources (e.g. use of statistical tools / suggestion to include in their study all the students in the school instead of the students in the classroom) that could facilitate the learning process with regard to the defined learning potentials. In this way, teachers extended their NCS experience to consider aspects of

teaching and learning and to connect the statistical objects they negotiated with features, learning potentials and resources that broaden their view towards these objects.

Another example is the case where, during NTS, the teachers or the researchers asked for clarifications regarding particular teaching decisions or suggestions. In this way teachers reconsidered their choices and developed a deeper understanding on the underlying concepts or possible conceptual connections. The following example, from the 7th meeting, is indicative of this case. In this extract Marcos was trying to explain his choice to use mean values instead of median when students study the difference in our ability to recall words and no words.

R1: Marcos, why did you choose to use the mean values here?

Marcos: It actually depends on what you want to see.

Chloe: And what about you? What do you want to see?

Marcos: Look. It is true that with the median is easier to manage the results, I mean it could be easier to find subsets that can give a difference on median that is so big or bigger than the one we get. But on the other hand... What if the difference is small, like here? If I was to choose from a students' perspective, I would choose the median, but not with a very small difference. I mean maybe there are other parameters that result in such a small difference. I am not sure what I would say to students for a very small difference.

This episode continued and lasted for about 4 minutes during which Marcos developed arguments to explain his choice. In this way, Marcos got insight not only in his didactical choice but also in the role of the mean value and the median in the study of differences between two variables. Such an inquiry, although it refers to NTS, was also helpful in illustrating statistical concepts and thus provided meaning to NCS as well. Almost all the teachers of our study, in their final interviews, referred to the positive impact of their inquiry in teaching on their content knowledge. This was either because they were facilitated by their colleagues or the researchers' examples and explanations or because of their attempt to help or convince their colleagues, which guided them to develop appropriate examples or arguments and thus helped them to deepen in their own understandings. In both cases, the context of the CoP which encouraged the collaboration among them played a determinant role on this interaction. Below, we present two characteristic extracts from the final interviews.

I feel I gained a lot, especially as a learner. You see, the concepts we decided to work with in the classroom were blurred for me, too. It was mainly Dinos' examples and explanations that helped me to understand first these concepts and consequently what we were going to do with the students. (Chloe, final interview)

These discussions helped me to develop a deeper awareness of many issues. I mean, when you are trying to take a stand towards an issue or a particular decision, it helps you either to get a more clear position, by developing a deeper understanding or to consider new views or aspects that were out of your attention. (Marcos, final interview)

Conclusion

This study aimed at getting insight into the interaction of NCS and NTS in the context of a CoP. The results showed that both processes were mobilized either by the nature of the task itself or by reasons that are related to the teachers' needs and the context of their work inside the CoP. Moreover, we saw that NCS process, apart from teachers' content knowledge, helped them to enrich their teaching repertoire (appreciate learning potentials, explore features, get access to new resources) as well as to strengthen their confidence in handling particular statistical concepts inside the classroom. Similarly, NTS process, apart from a space for inquiring teaching and learning, was also a starting point for the teachers to develop deeper understanding on statistical content, to make conceptual connections and to acknowledge different dimensions of the underlying problem. These results go beyond the work of Heaton & Mickelson (2002), which shows the importance of the complementarity of the two processes in the professional development of teachers, to give empirical evidence of how the one process provide feedback and meaning to the other. Moreover, the collaborative context of a CoP acted supportively in the interactions between them. Thus, such a context, that fosters the co-existence of NCS and NTS, seem to help teachers not only to experience statistics as learners, but also to link this experience with classroom reality.

Last, this complementarity and feedback are especially important to the professional development in the case of statistics since the stochastic nature of the content on the one hand, and the unfamiliarity of teachers with the statistical tools on the other hand, constitute factors that, as we saw, reinforce the interactions between NCS and NTS.

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