# COLLABORATIVE WORK IN STATISTICS CLASSES: WHY DO IT?

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*In Portugal like in many other countries we can find statistics in the mathematics curriculum, and statistics is taught in mathematics classes by mathematics teachers until the university level. During the compulsory levels most Portuguese students learn statistics in a traditional way. In this paper, we analyse dialogues of 7th grade students during collaborative work. The main objective was to understand some benefits of this kind of work on students' statistical reasoning. Our results suggest that collaborative work improves students' statistical reasoning as a result of the discussions and clarifications of their ideas and resolutions but also shows that this kind of work plays an important role in supporting students' development of positive orientations towards statistics.*

## INTRODUCTION

Today the majority of the countries are prisoners of numerical information, and the last 20 years highlight the potential of statistics in the development of research in different areas of study. Political, social, economical and scientific decisions are frequently made taking into account data provided by statistics. Arguments stated by media are supported by data, and, at times, the same data even generate different conclusions. In order to be critical in such situations we are compelled to develop statistical reasoning that will allow us to select the relevant data to form either a critical opinion or a common sense one. To be statistically knowledgeable it is essential for today's citizens to be critical regarding the available information, to understand how the information is generated and to communicate, as well as to be able to make personal or social decisions taking statistics into account. In other words, all citizens must have access to a formal education in statistics. Consequently, we find statistics literacy as a part of the political agenda of many countries. For Gal (2000), statistics literacy is one of the goals of the syllabus when it comes to professional training in many diverse areas.

In order to promote statistics literacy we must think of mathematics teachers during the compulsory school. Mathematics teachers face an odd situation when they have to teach a statistics unit. From one perspective, they have to approach this unit through exploratory situations and activities from small projects. However, during their pre-service teacher training as well as during their in-service teacher training, they have had few chances to experience first hand this innovative teaching practice. According to Gattuso (2006), to modify the traditional way in which statistics has been taught and learned in mathematics classes of mandatory education, mathematics teachers have to be convinced that statistics is one of the most useful themes for their pupils. In addition, better pre-service and in-service teacher training for mathematics teachers in statistics (Gattuso & Pannone, 2002) is needed, and their didactic knowledge related to teaching statistics must be enriched (Franklin & Mewborn, 2006). The conceptions of each teacher concerning statistics, statistical knowledge and didactic statistical knowledge determine how the work unfolds with the pupils.

In this paper we clarify by psychological arguments why students learning statistics in mathematics classes should do it in a collaborative way because they will have more opportunities to explain statistical processes, interpret statistical results or combine ideas about data. If mathematics teachers understand this, they will feel more comfortable in using collaborative work in their classes.

## A PSYCHOLOGICAL EXPLANATION ABOUT LEARNING STATISTICS IN A COLLABORATIVE WAY

In many countries, including Portugal, the curriculum guidelines call attention to the necessity for pupils to work collaboratively in mathematics classes and particularly when studying statistics. However, the emphasis on this way of teaching and learning statistics challenges teachers, statistics and mathematics educators, and others who conduct research in

© ICMI/IASE 2008. In C. Batanero, G. Burrill, C. Reading & A. Rossman (Eds.), *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics. Challenges for Teaching and Teacher Education. Proceedings of the ICMI Study 18 and 2008 IASE Round Table Conference.*

this domain. Gal and Garfield (1997, 1999) point out one of the main goals of statistics education is the development of the ability to communicate statistically in order that pupils gain experience with statistical reasoning. Speaking and writing is essential if we want pupils to be critical and reflexive toward statistical contents that are present in the most diverse situations. The use of statistics terminology must be promoted based on the construction of accurate arguments. Only in this way is it possible to develop positive attitudes regarding statistics. Therefore, only when concepts are understood by pupils in contexts like real life projects is it possible to develop understanding of powerful concepts.

In a recent work, Graham (2006) suggests that, before initiating the study of statistics, teachers should explore different arguments rooted in common sense and involving negative attitudes of pupils towards statistics. Such discussions will ‘awake’ pupils for the ‘great ideas’ concerning statistics. In the classroom, when pupils argue among themselves in pairs or in small groups, each one taking into account his personal experiences, knowledge and abilities, has to negotiate with the others the meaning of the content and the knowledge required to perform the task. Therefore, the ‘other’s voice’ is needed to bring up an alternative to each individual perspective and to make visible all the interactions that happen within a task.

However, beyond the individual contributions that each one of the pupils can give, social interaction is established in a context that generates expectations, interpretations for the situation and space for the negotiation of strategies needed to perform the task. Thus, we can state that the context is not neutral regarding the pupils’ performance we observe while pupils work with each other nor can it be limited to the physical space where the interaction occurs, as it changes constantly during the development of the social interaction. In the classroom, when two pupils actively commit themselves to solve a task collaboratively, they are using different arguments and points of view, which means they are using their cognitive trace. But the pupil also has to manage the social trace of the interaction that is essential for a collaborative context and that can be expressed by the other’s behaviour and by his interpretation of that same behaviour. Therefore, it is necessary to learn how to manage an interpersonal relationship while negotiating different approaches and solving strategies. And a pupil is not a mere spectator when he is listening to his peer. On the contrary, he is rather active. Both partners have to justify their arguments to each other as well as to negotiate the meanings of the concepts.

To work collaboratively does not mean that pupils only produce different answers. It is necessary that they commit with one another in a dynamic way; that is, it is necessary that both (re)construct arguments, strategy meanings and resolutions. Consequently, the sequences of tasks or activities that the teacher chooses are crucial when we conceive learning in which the individuals are actively involved as participants and not as mere containers of knowledge. The interest of the teachers in educational practices that facilitate collaborative work is influenced by their understanding of the learning process, and that is why teachers should experience those practices during their training. If they continue to think that teaching statistics is just doing computations, later in their classes they will reproduce this behaviour, and the students will not have the opportunities to design projects, analyse data in real contexts or understand statistical measures.

At the end of the 1980s, Gilly, Fraisse and Roux (1988) noted that when pupils are working collaboratively in a task, we can often observe some silent moments that reveal an individual search for a solution. During these moments, pupils are mobilizing a set of abilities and knowledge they consider necessary to successfully complete the task. Later on, one of them can initiate an interactive sequence provoked by his proposal for a solution strategy that, in turn, can provoke a reaction in others in the group. This interactive sequence that can last a few minutes or just brief seconds finishes when the pupils (a) are at a stand still, (b) reach a solution already proposed by one of them, or (c) reach a new solution co-elaborated by the group. The researchers identify four types of co-elaboration that are present when pupils work together. The ones that generate more progress in the pupils are the co-elaboration by consent and the co-elaboration by co-construction.

In co-elaboration by consent, pupil A elaborates or sketches a solution and proposes it to pupil B with whom he is working. Pupil B does not oppose or disagree but listens and gives a positive feedback that can be verbal or gestural. Pupil B, who does not have a passive attitude, as he listens and follows everything his colleague says and does, seems to construct, simultaneously, a similar reply to pupil A. The adhesion to the reply of the colleague is not false. On the contrary, it is a cognitive agreement in the form of a co-elaboration by consent. Accepting the arguments stated by others works as a positive reinforcement that controls the reply proposed by one of them but accepted by both. Because throughout the task the roles can be reversed, it is difficult to know if pupil B acts in this way because he does not have anything better to say or if, although he might have a different strategy or a different solution, he allows pupil A to express his thoughts.

In co-elaboration by co-construction, pupil A starts a sentence or idea, and B continues it. Then, pupil A retakes the idea when B finishes, and thus successively, they co-elaborate a solution together. It is not easy to know if each one of the pupils would come up to the same solution if they had been working separately. We only observe that each one uses the advantage of working collaboratively and uses his peer's idea for his own reasoning. Each one of the pupils strengthens what the other says by using it. However, this apparent harmony does not exclude the possibility that the interventions of one pupil might disturb the other one or even that they provoke an unlike idea that would never come up without this dynamic. This type of co-elaboration has a double effect for each one of the individuals: a pool of possible solutions emerges and, at the same time, it provokes disturbances in the solutions initially found.

The work of Gilly, Fraisse and Roux (1988) show us that students appear to learn better if they work collaboratively in small groups during a resolution of a task. Concretely, in statistics several researchers found similar results (Carvalho, 2001; Cobb, 1999; Garfield, 1993; Giraud, 1997; Meletiou & Lee, 2002). However, just being involved doing a task is not enough to ensure learning. The teacher has a crucial role to play, as he designs the class work and chooses whether the students will learn statistics by computations or by doing a collaborative statistics project.

## METHOD

The data we present belong to a larger quasi-experimental study conducted during two consecutive academic years, involving 533 pupils aged between 11 and 15 years old from the 7$^{th}$ grade attending a secondary school in Lisbon. The main goal was to study in depth, in classroom context, how peer interaction generates progress on the statistical and cognitive performances of the pupils (Carvalho, 2001). In a first stage, the pupils individually work on a computation task about means and medians and take a cognitive test. The performance of the pupils on these two instruments allowed the author to put the pupils in pairs (n=136).

In this paper we analyse some interactions during a second phase, when pupils work collaboratively in pairs on a set of tasks not traditionally related to statistics. Teachers claim to very rarely use such tasks when teaching statistics. We asked the pairs to discuss their solution strategies in order to have a final answer. Each pair only had a sheet of paper for their answers, which we analysed. Their interactions were recorded and transcribed later on.

Task: In a factory, five of the workers were randomly chosen to do a study about their salaries. The salaries are given in the following table:

| Worker | A | B | C | D | E |
|---|---|---|---|---|---|
| Salaries (Euros/month) | 270 | 210 | 300 | 240 | 900 |

1. Do you think that the five workers would agree if we say that the great majority of them have a salary equal to the mean? Why?
2. Do you choose the mean or the median to represent the salaries of the workers? Why?

## RESULTS AND DISCUSSION

A first look at the data shows that the study of students' interactions, tasks and instructions presented to pupils is essential to the comprehension of the way they appropriate their knowledge and construct their statistical meaning. Peer interactions, during collaborative work, were a powerful means of implementing new solving strategies with better performance for most students. This fact is one of the most interesting aspects we observed because it lights up the power of collaborative work as a common practice in the classroom.

The most frequent way pupils solved this task was by comparing the mean value with all workers' salaries and the median with the mean value. This apparent simplicity of the procedures and calculations gives the illusion to teachers and pupils that pupils are acquiring a set of knowledge. However this kind of task solution shows that pupils acquired only an instrumental knowledge, revealed by mastering isolated rules and algorithms learned through repetition and routine, instead of a relational and significant knowledge that can be recalled whenever new situations demand it.

The pupils often do not discover any mistakes in their arguments until their peer points them out. That happens because they have to discuss with each other until they agree on a solution in order to write it down. When we analyse the interactions of the 136 pairs during the resolution of this task, we can also verify that the more frequent co-elaborations were co-elaboration by consent and co-elaboration by co-construction. These were also the ones that generate more progress in the pupils' understanding and reasoning about measures of center, beyond a computational level. Consider this example of a peer interaction extract that we classified as a co-elaboration by consent:

> B: They don't earn the same.
> C: That's right. They must have different jobs.
> B: This one earns more. He has a bigger salary. He must be the boss.
> C: The boss earns more and this is...
> B: Unbalanced …. and then, it seems that all…
> C: That all earn the same if we just do the mean.
> B: The mean is not the best way; it doesn't show that there are differences (...)

In the next example we have a co-elaboration by co-construction. In this case we observed a true co-construction of a possible solution where a pool of possible solutions emerges and, at the same time, it provokes disturbances in the solution initially found.

> M: We have to add the salaries…
> G: And then we must divide by five. It's going to look like they all earn the same, but it's not true because the boss…
> M: Earns much more than the others do.
> G: Specially when comparing with the employee that earns the lowest salary.
> M: The salaries are too different and cause the mean to be wrong.
> G: The mean is not wrong. This is ok.
> M: I think this makes it look like they earn much more…
> G: The mean is ok. We added the five salaries and then we divided by five.
> M: Yes, I know but there is something here. Are these the salaries of all the employees?
> G: May be… Or, maybe they just choose a few?
> M: We can think…
> G & M: They were badly chosen. [simultaneously]

The interactions observed and generated by the same task show that the way pupils work on a task in the classroom affects the quality of the pupils' performance. Therefore, how can we promote situations in the classroom so that pupils work collaboratively? The answer to this question is a real challenge because we have to modify the way we teach and learn statistics in mathematics classes with mathematics teachers, but to do such modifications we must think about the initial training and ongoing professional development of mathematics teachers.

## SOME IMPLICATIONS FOR TEACHER TRAINING

Regarding professional practice several authors show that teachers carry out little collaborative work among themselves (Hargreaves, 1998; Ponte & Serrazina, 2004). However, carrying out collaborative work seems to be essential to improving professional practice because it is through the exchange of ideas and materials among teachers who have common problems and needs that new ideas emerge for the introduction of new activities, new practices or new competencies. When teachers work collaboratively the relation between each of the protagonists is very close, making it easier to share successes and hindrances, allowing each one to learn from others' contributions and therefore keeping motivation high. How teachers feel about statistics and statistical knowledge affect their work with pupils. A mathematics teacher that feels uncomfortable with statistics may have a tendency to reduce or to omit the statistical subjects in his classes. Also, the teacher might not be able to have a good statistical discussion with pupils. Working collaboratively with other teachers can help the teacher (re)construct new conceptions concerning statistics and how to work with pupils in mathematics classes.

In order to change the teaching of statistics in schools, we must change the preparation of mathematics teachers during the initial training. And a way of doing this is by promoting collaborative work among pre-service teachers during that training. In a study carried out by Antunes and Carvalho (2005; 2006) with pre-service mathematics teachers, the authors observed that collaboratively planning classes has an important role for pre-service teachers because it was during the joint planning sessions that several issues were discussed and negotiated, namely the best way to clarify statistical knowledge or work on the statistics subjects with students. By sharing ideas, pre-service teachers enhanced their determination to act and increased their confidence so they would be able to run risks teaching statistics, creating the conditions to do so through dialogue, negotiation and joint reflection. This mutual learning contributed to facing challenges and problems felt by the group and also by each member of the group. Therefore, collaborative work between pre-service teachers seems to contribute to reflective practices where they constructed new meanings based on what they already knew, relating this meaning to their previous experiences and not necessarily to the meaning given by others.

Finally, a last thought about the potential of working with pupils in real situations during the statistics classes; by doing so the teacher can develop a research attitude towards his own teaching practice. Effectively, when a teacher becomes involved in situations that relate to pupils' interests and perhaps to his own interests, he creates conditions to investigate his own teaching practice and problems directly related to these practices. Nevertheless, this attitude demands a reflexive action that should be shared, and, as such, the teacher should belong to a research team.

New curriculum and methodology guidelines suggest that when teachers are involved in research projects it can change how mathematics is experienced in the classroom, especially in connection to statistics. One possible way to change this scenario results from collaborative work with mathematics teachers in research projects. Undoubtedly, this is probably an ideal way for changing some of the practices that occur in many classrooms and a challenge for those worried about statistics education.

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