LEARNING AND TEACHING STATISTICAL INVESTIGATIONS: A CASE STUDY OF A PROSPECTIVE TEACHER

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More than a collection of tools to deal with problems, statistics provides a comprehensive framework to think about the world. One way of using it is doing statistical investigations (SI). In this communication, we present a case study of a prospective primary school teacher regarding her perspective on teaching and learning SI. To do so, we analyze her written report of a SI, a questionnaire, observation of a SI she carried out in a grade 3 class, and interviews. Results show that this prospective teacher has difficulty in planning a SI for her students, mainly because she sees this activity as a sequence of techniques to be applied. This suggests that in teacher education programs, the analysis of what is involved in teaching statistical concepts through SI must receive specific attention, instead of using SI only as a context to apply concepts and work with data.

INTRODUCTION

Statistics nowadays has great importance in society, since there is an increased need to make decisions based on data (Wild & Pfannkuch, 1999). Many curricular documents for kindergarten and elementary school (ME, 2007; NCTM, 2000) emphasize this topic since the early grades. According to Scheaffer (2001), the main goal of statistics education is to promote statistical literacy, so that all citizens are able to interpret, critically evaluate and communicate about statistical information and messages (Gal, 2002). Statistics must be taught in schools in order to generate citizens that have a critical stance at the information that surrounds them. This requires teachers to hold a strong knowledge of this topic.

In teaching statistics there are two different views. In the first, the main concern is to understand statistical concepts, representations, and procedures. This perspective promotes the learning of data representation in tables and graphs and of computation of statistical measures, often out of context. However, as Scheaffer (2000) indicates, this often translates in statistics education seen as a series of techniques instead of being a process to think about the world. In the second view, concepts are learned in context and statistical investigations (SI) are used to develop statistical literacy, involving students in active learning processes. They pick a theme of interest, define goals, select data collection instruments, choose samples, collect, analyze and interpret data, and answer the proposed questions (Batanero & Godino, 2005). In this way, they acquire the ability to appreciate the importance and the difficulty of the statistical work and its interest in real life problem solving. If this is to happen, SI must receive attention in teaching education programs, both in statistical and didactical terms, because as Fernandes (2009) indicates, beyond a deep statistical knowledge, it is also important to improve prospective teachers' didactic knowledge.

Prospective teachers should have the experience of doing SI before taking them to the classroom (Makar & Fielding-Wells, 2011). To support them in this, it is necessary to understand in which ways prospective elementary teachers learn and teach SI. Specifically, we want to answer the following questions: (i) *What perspective does this prospective teacher hold about each phase of the SI?* (ii) *How does the prospective teacher implement each phase of the SI with students?*

CONCEPTUAL FRAMEWORK

Several authors point out the value of doing SI to promote the development of students' statistical knowledge (CBMS, 2001; Heaton & Mickelson, 2002), namely as producers and consumers of statistical information (Fernandes, 2009). During a SI, students may move through the phases of the PPDAC cycle (Problem, Plan, Data, Analysis and Conclusion) referred by Wild and Pfannkuch (1999). To conduct such work, teachers need solid statistical knowledge, as well as knowledge of how to implement SI with students, how to facilitate students' reasoning with data and a disposition to teach and learn in a way that nurtures the knowledge obtained through

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investigations (Heaton & Mickelson, 2002). Nonetheless, there are very few studies regarding the undertaking of SI in class, and even fewer concerning prospective elementary teachers.

As Makar and Fielding-Wells (2011) indicate the "problem" phase is very important, since it works as an initial hook and focus for all the process. In their perspective, the questions should motivate students, relate to their interests and have a competitive and challenging nature, but also a reachable cognitive level. Heaton and Mickelson (2002) add that questions should be open, statistically rich, with content suitable for students and relate to other areas of the curriculum. Nevertheless, in the classroom, this phase is often forgotten. In their study with prospective teachers (grades K-6), Heaton and Mickelson (2002) indicate that they frequently pose questions too simple ("how many") without a clear goal besides obtaining an answer. When implementing SI with students, these prospective teachers choose themes from sciences, social studies and language arts, but data synthesis goes no further than a descriptive summary of data. During the planning of a SI, it is important to go back and forth between the initial question and the investigation design (CBMS, 2001). In this phase, teachers should transfer some of the control to students, giving them responsibility in planning the investigation (Heaton & Mickelson, 2002). Teachers should help students in some essential methodological decisions like the use of populations and/or size of samples (Makar & Fielding-Wells, 2011). The third phase of the investigative cycle includes data collection, data control and data "cleaning" (Wild & Pfannkuch, 1999). According to Makar and Fielding-Wells (2011), teachers with experience in orienting students' methodologies can easily recognize opportunities for meaningful learning during students' discussion of problems emerged from data collection. The "analysis" phase requires data exploration and analysis and the generation of hypotheses (Wild & Pfannkuch, 1999). Letting students represent their own data may encourage the process of changing representations to allow the emerging of alternative visions (Makar & Fielding-Wells, 2011). During data collection and analysis there is a need for familiarity with concepts and ideas related to descriptive statistics and with graphical and tabular representations. For participants in the Heaton and Mickelson's study (2002), making a graph was the endpoint of data collection, with no meaningful connection back to the initial question of the investigation, revealing participants' "own uncertainty about the components and complexity of reasoning with data" (Heaton & Mickelson, 2002, p. 49). Finally, in the "conclusion" phase, Wild and Pfannkuch (1999) include interpreting data, drawing conclusions, deriving new ideas and communicating results. Additionally, CBMS (2001) denotes the importance of considering if the initial question was in fact answered, being aware of some of the difficulties that come from sampling and inferences. If necessary, the initial question should be reformulated and a new investigative cycle should be performed (CBMS, 2001). In this last phase, is also essential the knowledge of how statistical conclusions and inferences are reached (Gal, 2002).

METHODOLOGY

This study follows the interpretative paradigm and a qualitative approach, in a case study design, using multiple data collection instruments: a questionnaire, interviews, observations and document analysis. The participant is a prospective elementary teacher (grades 1-6), with the fictitious name Monica. The data analysis follows the different phases of the investigative cycle, including both Monica's perspective about each phase of the SI as well as how she implemented them in the classroom. In her 2nd year of studies, in 2010/11, she took the single course of the teacher education program dedicated to statistics. During the course, prospective teachers worked statistical concepts through the exploration of situations in real contexts (using and discussing tasks that could be used as teachers), and discussed how to pursue SI using different data collection instruments. Monica also carried out, collaboratively, a SI about sports, a theme chosen by her group. During their investigations, participants were asked to present their work to the class and write a report, including an introduction (motivation for the theme/initial question and relevance), data organization, analysis, conclusion and reflection about the work done (including a discussion about the possibility of doing the SI with students). Participants spent on it most part of the semester, but mainly outside the classroom. Towards the end, each group received feedback from the professor with questions to reflect about what was done and never merely corrections. After the presentation they received a final grade for the process and final product, where Monica obtained a grade of 14/20 (roughly B$^-$), which end up to be her final grade at this specific course. During her

3rd year of the education program, in 2011/12, Monica answered a questionnaire with content regarding statistics and didactics of statistics. There, she revealed some misconceptions that were discussed later during the interviews. In the year 2012/13, during the 2nd semester of the 4th year, she was enrolled in a supervised teaching course, having to teach a few days to a grade 3 class. Aside from an initial interview (II), Monica was asked to implement a SI with her students, which she divided in two different classes (two weeks apart). Those classes were observed and video recorded and interviews were made before (IB) and after (IAC) each class to discuss the plan and to reflect about what happened in class.

RESULTS AND DISCUSSION

Problem

During the education program, Monica's group chose to do a study about the sports practice, because of the current trend towards childhood obesity (Report). When required to do a SI of her interest, but with students in mind, we observe that Monica is able to choose a topic that can generate a discussion about other area of the curriculum, social sciences. Monica's perspective of the first phase of the SI seems to be associated with a need to answer or discuss major problems of society (like obesity) that she can predict as being part of her future as a teacher. This shows that she is aware of her surroundings and is able to take that awareness to the classroom. So, the theme was not necessarily a theme of her personal interest, but more professional related.

Regarding the way she implemented this phase with students, Monica indicated as her major difficulty the choice of the theme: "Now, the difficulty is (…) the topic that interests them" (IB). For her, a SI should start by a problem proposed by the teacher and she used that method:

> We already know each other for a while, right? But I don't know several things about you. I want to know some characteristics so that we can study them. I want to know your characteristics. (…) Things I still don't know, nor can see. (…) What do you want to give me to know? (Class)

Monica introduced this SI with a simple question with no input from the students, so they, at least, formulate it and make it theirs. There was also no wider purpose besides collecting data related to those characteristics. Monica chose an initial question that is somewhat related to students, but lacking the challenging and competitive level that Makar and Fielding-Wells (2011) refer as important to motivate. Nonetheless, she is able to create other themes that allow the SI to be introduced more spontaneously and naturally in the classroom. For example, they could pursue a SI as a consequence of an informal conversation between students, "They could be talking about the profession they want to have. Two students could be discussing the different professions they want to pursue" (II). It can also come up as a connection between statistics and other mathematics topics, "Yes. Today, for example, I think it would have been a good day to implement. (…) They learned the meter, the centimeter, the decameter… They learned the measure units. And two or three students measure themselves. That could also…" (II). It can also be as a connection to other area like social sciences (healthy food consumption), "I was thinking about snacks, but then that implies a lot of things and the majority of them do not bring snacks and can generate lots of discussion" (IB). We conclude that Monica is able to generate good ideas to implement SI with students, where the theme comes up more naturally. Nonetheless, what happened in class was a simple initial question, formulated only by the teacher, with a narrow goal for collecting data.

Plan

During the interviews and about the sports investigation Monica showed some difficulty with the sample and population concepts, since she had the idea that we always need to use a sample and to choose it we "go to a school, to a classroom and choose a classroom of teenagers of a school" (II). This choice is probably related to the SI her group did, where questionnaires were applied to a class of 1st graders. To Monica, a population is always too big, maybe because she associates the population concept to all Portuguese or world population. Additionally, Monica holds a perspective of a SI as being required to "make a questionnaire to apply afterwards", like done in the past, not allowing for other data collection instruments (II).

During the implementation of the SI in class, in the "problem" phase, we observed Monica generating a problem and giving beforehand the plan of using questionnaires and also the types of questions students could or could not use. Only then Monica gave some responsibility to students in the construction of the questionnaire, still being afraid of the unpredictableness of a SI, mentioning "They are so unpredictable that I'm even afraid of what they will answer" (IB). To overcome that fear she created a list of several questions proposed by the students and chose from the list "two to three questions" (IA): "How many sibling do you have?", "What is your favorite discipline" and "What are your hobbies?". Nonetheless, Monica's choice was not discussed with students, not making clear for them what constituted a good or a bad investigation question:

Student: What are your father and mother's names?
Monica: No [without an explanation about why she was not considering the question]. (Class)

At this phase, we observe that most of the planning decisions that Monica shows are connected to the way her group carried out the SI during the teacher education program (choosing a theme, constructing a questionnaire, using a sample, choosing a classroom…).

Data

We do not have much information about Monica's perspective about data collection, since her written report does not explain how the collection of data occurred and does not show any intermediate step between the questionnaire used and the frequency tables and graphs displayed.

In class, Monica assumed total control. After deciding which questions to pursue in the investigation, she elaborated a table for each question in a document that she projected. Monica does not look at these tables constructed simultaneously with data collection as a way of organizing data (IA). Since Monica is uncomfortable with the unpredictableness of SI, she assumed control in this phase, indicating that, probably because she was in control, this phase was the one that went better in class:

Researcher: What do you think that went better in the class?
Monica: When we were putting all the data in order in the table. (…) the collection of data. (IA)

Possibly due to the simplicity of the initial question and the lack of reasoning during planning, data collection was not used to its total potential in generating problems that students needed to overcome and in allowing them to reason about data (Makar & Fielding-Wells, 2011).

Analysis

In Monica's group investigation, it is presented a frequency table and a graph for the data from each question of the questionnaire. In the analysis, they literally read all the data from the representations, stating each value or category and its corresponding frequency. Other times they described each statistical measure determined (without an actual interpretation of what it really means). The only concept they interpreted regarding each context was the mode, even in the case of numerical data. During the interviews, Monica also associated the data analysis to the description of frequencies and the identification of the mode:

Researcher: We pick that classroom, implement questionnaires to that classroom, and then what? What do we do next to do the statistical investigation?
Monica: We have to read the results, take conclusions.
Researcher: What is that, reading results? (…)
Monica: See who likes football… count… who practices more, if they practice or not. (II)

We conclude that Monica's perspective about data analysis is pretty rudimentary, consisting simply in the construction of a frequency table, a graph, calculating every statistical measure possible and then reading literally those representations, not really interpreting the data. This perspective is going to be very evident in the implementation she did in the classroom.

After collecting the data in a table, Monica took students to do a frequency table and a graph. In the case of the frequency tables, students struggled to realize its need (since they had the

collection data tables), even with some scaffolding from Monica. It seemed easier to students to recognize the construction of graphs as a next step. Monica assumed one more time the control and was the one who constructed the frequency table on the board, with students' input at some moments. Then, she spent some time analyzing it, focusing on what each absolute frequency meant and on the mode concept Although students could choose the graph representation and construct it, once again, the construction of graphs appeared as a needed step to complete the SI (Heaton & Mickelson, 2002) and it was not given any emphasis in the discussion of the advantages of graphs in relation to tables. In Monica's citations, we observe a tendency to follow in the classroom the process Question-Questionnaire-Data collection-Table-Graph, which corroborates her perspective of a SI and follows Scheaffer's (2000) critics. We realize that data analysis, besides appearing in Monica's SI report and interviews, is not a phase that she gives special attention in class. There was some data analysis when the data was in a tabular representation, but as happened in her past, did not go further than the category/value with greater frequency and a literal reading of the representation.

Conclusion

Monica's group formulated conclusions about their theme in the reflection chapter of the report, but were mostly generalizations about the data like "the most practiced sport is swimming" (Report). Similarly, Monica showed a tendency to generalize results regarding the favorite sports of a classroom of teenagers, "The majority of that school" (II). She knew that what happens with that classroom "does not happen with the others", but her only alternative in order to be able to generalize was "to do with the other classrooms too" (II). This demonstrates that Monica does not understand the sample concept and, especially, does not understand as conclusions and inferences are reached from a sample (Gal, 2002). Nonetheless, Monica's group was able to reflect about results and present other questions that arise from it, like "Do parents put their children in so many sports with a concern related to health or simply because they do not have time to be with them and in this way they keep them busy?" (Report). Hence, Monica's group concluded the SI with the possibility to generate other initial question and other investigative cycle. Still, Monica shows misconceptions about the concept of sample that influence her perspective about generalizations and inferences based on data.

Regarding Monica's implementation of the SI, the conclusion phase was almost non-existing. After the construction of the graphs, Monica decided to discuss the errors in students´ construction, like she had planned (IB). Even when Monica is asked about the purpose of the investigation, she still does not see the need for making a conclusion with the class to end the investigation:

Researcher: What was the initial question? (…)
Monica: What are your characteristics?
Researcher: And what was the answer, after doing all this investigation?
Monica: That there are x students with 0 siblings, there are other that only have 1 sibling and other with 2. And I get to know who have siblings and who don't in the class. (…)
Researcher: And those conclusions you told me, do you think students also came up with them?
Monica: I think so. I think we talked about it in the other class [first class of the SI]. (…)
Researcher: Did you do it when you analyze the tables?
Monica: Yes.
Researcher: Then we got the answer to the [initial] question already with the tables.
Monica: They had.
Researcher: So this [the graphs] weren't needed to get the answer to the investigation?
Monica: No. I think it wasn't necessary. (IA)

This shows that Monica got students to conclude the SI already during the analysis of the tables, and everything they made afterwards was practicing statistical procedures. We can also observe that she does not give a meaningful purpose beyond the data collection to make sense of the SI, probably due to her inability to make students go back to the initial question throughout all the process (CBMS, 2001) and as consequence of the simple and aimless initial question chosen. This is similar to what happened to most participants in Heaton and Mickelson's study (2002).

CONCLUSION

Monica's ideas about SI show a tendency to follow the process theme - questionnaire - sample - frequency table - graph, with no understanding about its rationale. This is certainly connected to what she did in the SI she carried out during the statistics course, where it was required to do so. In addition, she has some misconceptions about the sample and population concepts, influencing the way she constructs statements based on data. She demonstrates, carrying out a SI with students, more difficulty in the first and last two phases of the cycle (problem, plan, analysis and conclusion), where it is needed more didactic knowledge, since it is not possible to simple translate her past experience as learner to the classroom in order for students to actively participate and make sense of the investigation. She wants to give control to students at some of the phases, but since she does not like unpredictable answers, she assumes the leadership of the investigation at several points (theme, questionnaire, table). As Burgess (2008) points out, teachers need more experience learning statistics through investigations, so that they can have opportunity to develop their common content knowledge of statistics. This was most noticeable about Monica. Her lack of experience in doing SI, for example using other data collection instruments or using SI as a context to teach statistical concepts, truly influences her teaching and her perspective of what is a SI and what it looks like in class. Even with Monica being only a case study and, therefore, not being able to be generalized, we can take some learning from this. A possible implication is to move beyond what is happening in statistics courses, requiring prospective teachers to pass through all phases of the investigative cycle and demanding the use of all statistical concepts learned. Instead of that, during the teacher education program, prospective teachers should have more worthwhile opportunities to experience SI as a way of learning statistical concepts in context, where they decide the statistics they need, so there is a purpose and a sense for every action.

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