Statistics education from the perspective of statistical literacy: Reflections taken from studies with teachers

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**Statistics education from the perspective of statistical literacy:
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Abstract: The aim of this article is to discuss aspects of statistical literacy from research on statistics education conducted with teachers and developed by the Research Group on Mathematics and Statistics Education (GPEME) at the Universidade Federal de Pernambuco (UFPE). These investigations were influenced by international discussions on a perspective of statistical literacy that focuses not only on knowledge and technical procedures of curriculum content in statistics, but also on developing critical attitudes towards approaching data. The reflections are based on the analysis of research with teachers of different levels and teaching modalities, who engaged in problem-solving activities associated with various topics in statistics. The article problematizes the challenges of addressing statistical literacy in the initial and continuing education of teachers who learn and teach statistics. Discussions are included on research that has methodologically addressed teacher participation in groups that involve cooperative and collaborative processes and that associate teacher education with this broader perspective of statistical literacy. The research presented offers empirical evidence that an effective pedagogic strategy to improve teachers' knowledge of statistics is to explore of dialogic situations in which they may be led to reflect on their own interpretations of statistical data related to contemporary contexts that involve different themes. Reflections on the research results also indicate some possible pedagogic implications and the need for future research that may better develop the topics studied.

Keywords: Mathematics Education; Statistics Education; Statistical Literacy; Statistics Teacher Education.

Introduction

Statistical information is present in several quotidian situations, such as reading newspapers and magazines, advertisements or in the work routines of certain professionals. This information may have repercussions on people's lives, since it refers to a great diversity of aspects, such as: economic indices; sports activities and events; voting intentions; educational rankings; climate forecasts and health. Evans (1992) emphasized that elements of statistical literacy that are related to the types of skills needed by people in everyday life are not only limited to the domain of calculation techniques and procedures. Wallman (1993) stated that statistical literacy as the ability to understand and critically assess statistical

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results that permeate our lives on a daily basis may contribute to public and private, professional and personal decisions.

Statistical literacy refers to the critical interpretations of a person's statistical information, considering the arguments related to data or phenomena presented in different contexts (Gal, 2002). This also implies that people need to know how to discuss or communicate their understanding of the statistical data that they interpret, offering opinions on the implications of this information and making considerations regarding the acceptance of the conclusions provided (Cazorla, Kataoka, & Silva, 2010). This perspective of statistical literacy, which promotes critical interpretations of this statistical information, is a very important social need, since it helps people to exercise their citizenship to the full.

In Brazil, from the end of the 1990s, recommendations began for the inclusion of statistics as curricular content linked to the teaching of mathematics from the early years of schooling (MEC, 1997, 1998). At the time, the introduction of statistical content in the curriculum posed challenges for teachers, who had never studied such topics, either during their initial or continuing education. Another important challenge was also related to the fact that at that time there was little national research on the subject and, therefore, there was a lack of support for schools and for teacher education courses so that teaching strategies on the recommended topics of statistics could be developed.

The recommendations for statistics education in secondary education were published years later with suggestions for structuring themes such as *data handling*, which involved statistics topics, counting and probability (MEC, 2002, 2006). These documents contained a prescription not only in the area of mathematics, but also in disciplines such as biology, chemistry, and physics, focusing on the importance of statistics for scientific education, as well as citizenship. However, within the above-mentioned documents, no mention was made of either the term or the concept of statistical literacy.

More recently, the National Common Curricular Base – known as BNCC (MEC, 2018) presented guidelines that reaffirm the importance of teaching statistics in the school curriculum from the early years. This document, which currently regulates the Brazilian curriculum, uses the terms mathematical literacy and scientific literacy, but does not explicitly mention the term statistical literacy.

Ainley & Monteiro (2008) argued that although the National Curricular Parameters (MEC, 1997) emphasized the importance of problem solving and the use of materials designed to provide support for implementing the teaching of statistics, it was nonetheless necessary to create situations so that teachers could be challenged to develop more reflective pedagogical approaches, and not simply apply curriculum prescriptions. Thus, research into statistics education should be used as an aid during the early years of initial teacher education, in order to support teachers whose confidence and experience in statistics was limited. Bezerra and Giritana (2013) also identified these obstacles in the initial education of teachers from the final years of both primary and secondary education, since the vast majority of undergraduate courses in mathematics in Brazil do not explicitly provide for concerns with statistics education.

One of the most prominent initiatives to strengthen statistics education in Brazil was the creation, in 2000, of the Working Group 12 in Statistics Education (GT12) by the Brazilian Society of Mathematics Education - SBEM (2020), which was a decisive milestone in bringing together researchers interested in the area (Ribeiro, Healy, Borba, & Fernandes, 2018). The GT12 also contributed to understanding statistics education as a research area with the aim of studying and understanding how people teach and learn statistics, considering cognitive and affective aspects, the epistemology of statistical concepts and the development of teaching methods and materials to promote statistical literacy (Cazorla, Kataoka, & Silva, 2010). Furthermore, research linked to the GT12 maintained an interface with other areas such as mathematics, psychology, pedagogy and philosophy education. Hence, the creation of the GT12 was responsible for mobilizing a greater number of Brazilian researchers interested in the area, thus expanding the theoretical and methodological discussions and pedagogical implications of studies on teaching and learning statistics.

Since the creation of the GT 12, it may be observed that research has been related to different themes on learning and teaching various statistical topics at different levels of education (Porciúncula, Samá, Rocha, and Felisberto de Carvalho, 2018). Over the years, the predominance of studies with an experimental methodological basis has been associated with other research approaches, which has provided a greater diversity of discussions on the conceptual bases and pedagogical implications for

statistics education in Brazil. Brazilian researchers have also established exchanges with other colleagues and international institutions, which has led to important debates such as the need to expand the perspective of statistical literacy (Borba, Monteiro, Guimarães, Coutinho, & Kataoka, 2011). Following an international trend triggered by organizations such as the ICMI - The International Commission on Mathematical Instruction (Adler, Ball, Krainer, Lin, & Novotna, 2005), research began to focus particularly on the initial and continuing education of teachers who teach mathematics and statistics.

The creation of the GT12 and the preliminary studies motivated the formation of several research groups, which became dedicated to investigating statistics education at the Education Center of *Universidade Federal de Pernambuco* (UFPE), as in the case of the Research Group on Mathematics and Statistics Education (GPEME), created in 2010 and whose production is discussed throughout this article. Although these studies were conducted in the state of Pernambuco, they were nonetheless linked to the construction and growth of statistics education on a national level. The aim of this article, therefore, is to discuss aspects of statistical literacy in research on statistics education conducted with teachers and developed by the GPEME at UFPE.

The initial research on understanding statistical data

Some of the first Brazilian studies that addressed the understanding of statistical data were developed on the Postgraduate Program in Cognitive Psychology at UFPE (Meira, 1997, Monteiro, 1998, Lima, 1998). This body of research explored the interpretation processes of graphic media following the sociocultural perspectives of internationally renowned research (Carraher, Carraher, & Schliemann, 1985). Carraher, Schliemann and Nemirovsky (1995) and Meira (1996) addressed the interpretations of statistical data presented in graphs published in magazines and newspapers. These investigations were primarily concerned with discussing the relationship between knowledge termed informal or out-of-school knowledge that could play an important role in interpreting statistical data.

Studies by Meira (1997), Monteiro (1998) and Lima (1998) identified that print media frequently uses statistical data to illustrate their journalistic arguments on a wide variety of subjects. In these media

contexts, the information presented in graphs, tables and infographics, is directly linked to the intentions of those who structure the material, and who are able to emphasize, mask or omit quantitative and qualitative aspects of the data. On the other hand, these studies also indicated the idea that interpreting statistical data is not an activity limited to automatically taking in information. On the contrary, people establish interpretation processes related both to the context of reading, and to their knowledge of quantity, number, reason, proportion, percentage and graphic representation and their previous personal experiences. Thus, cognitive and affective aspects are also included in people's interpretation processes.

The results of these first studies also made it possible to conclude that familiarity with the theme of graphs is not, in itself, a facilitating aspect of interpretation. Familiarity needs to be immersed in significant relationships between the interpreter and the statistical data presented in the graph. In other words, the importance of familiarity is not an aspect that occurs regardless of the situation. Another conclusion suggested by these initial studies refers to the fact that participant' academic qualifications is not a determinant of their interpretations, since it only constitutes one part of their human formation. People who interpret statistical data are not just statisticians, economists or mathematicians, they are not only professionals, but they are also citizens, consumers, fathers and mothers, voters and so on. From these multiple experiences of exercising different social roles, the participants brought their beliefs, desires and knowledge that were linked to their interpretations. When interpreting media graphs, the participants mobilized their previous knowledge and experience related to the displayed data. Therefore, the process of interpreting media graphs is not just made up of formal mathematical knowledge. These approaches were then similar to studies that discussed the relationship between schooling and the use of out-of-school knowledge in everyday social situations (Nunes, Schliemann, & Carraher, 1993).

Since studies in psychology have suggested significant pedagogic implications, they have become the starting point for other research studies on the formation of teachers who teach statistics. For example, Monteiro and Selva (2001) explored the process of interpreting graphs amongst elementary school teachers. Analyzes of the interpretations developed by the teachers suggested that they were unfamiliar with some of the terms related to graphs, such as axis and scale. Some of them experienced difficulties in

understanding the quantitative relationships involved in statistical data presented. On the other hand, data analysis revealed that the interpretation processes of teachers were also based on their opinions and feelings about statistical information. For example, one of the graphs dealt with the incidence of different types of cancer between men and women from 1990 to 2020. The authors identified that the personal involvement of participants with the topic of cancer seemed to be an important element of their interpretations. In the interviews, all participants expressed that they recognized the importance of teaching statistics in the early years of schooling, although they emphasized that they knew very little regarding this curricular content.

This initial body of research has helped to broaden and deepen understanding on the complexity of data interpretation by involving several elements and processes, thereby being configured as a problem-solving activity (Carvalho, Monteiro, & Campos, 2010). These studies have also led to understanding that representations of statistical data, such as graphs, cannot be conceived as facilitators for reading and interpreting data merely by being exposed to readers. Thus, it is necessary to have an organizational plan of teaching that considers the specificities of interpreting statistical data. Therefore, the important role of the teacher as a mediator in the processes of teaching and learning statistics is emphasized, which implies the importance of working on dimensions of statistical literacy during the initial and continuing education of teachers.

Aspects of statistical literacy in teacher education

In Brazil, the initial and continuing education of teachers still faces a major challenge due to several factors related to issues of infrastructure, theoretical and methodological conceptions, and financing policies. Perhaps the biggest challenge is the development of teaching processes that encourage reflective practices, which includes assessing their knowledge of curricular topics and their teaching practices. For Freire (1996) teaching requires critical reflection on practice. Thus, teacher education needs to be founded not only upon the development of skills and techniques for teaching. Freire emphasizes the need for pre-

service and in-service teachers develop critical analyzes of their own learning and previous practices in order to establish new, and better ways of teaching.

Gal (2002) problematized on the conception of statistical literacy related to "what is expected of adults (as opposed to students actively learning statistics), particularly those living in industrialized societies" (p. 2). Gal focused his discussion on the *reading contexts* in which people are consumers of statistical data, marking an important difference from the so-called *enquiry contexts* (Wild & Pfannkuch, 1999), in which people are the producers of statistical data. Reading contexts are also different from *school contexts* (Monteiro & Ainley, 2004), in which situations of data interpretation are intentionally planned to encourage the teaching and learning of statistics. Even considering the specificities of each context of interpreting statistical data, it is expected that a person may be a reader and/or a producer, depending on their engagement in a particular context (Gal, 2002).

Gal (2002) argued that statistical literacy involves the ability to interpret and critically assess statistical data in reading contexts related to everyday situations in which people may encounter statistical data, such as when they are at home watching television, reading newspapers, searching for or buying products on websites; when they are at work reading manuals or listening to instructions; as well as when they are participating in social or political events. Statistical literacy also involves the ability to discuss and communicate reactions regarding such information.

Gal proposes a theoretical model based on the assumption that "statistical literacy involves both a knowledge component (comprised of five cognitive elements: literacy skills, statistical knowledge, mathematical knowledge, context knowledge, and critical questions) and a dispositional component (comprised of two elements : critical stance, and beliefs and attitudes)" (Gal, 2002, p.3).

Knowledge elements	Dispositional elements
Literacy skills	Beliefs and Attitudes
Statistical knowledge	Critical stance
Mathematical knowledge	
Context knowledge	
Critical questions	

Statistical Literacy

Table 1 – Statistical Literacy Model

Monteiro (2016) argued that the term statistical literacy has been used for different approaches since the 1990s, by authors from different countries who began to relate it to the social uses of statistical knowledge. Carvalho (2001) argued that emphasis on the social function of statistical literacy contributed to this conception being approached as a panacea for solving the most complex problems related to the production and use of statistical knowledge in various sectors of society. Statistical literacy that enabled people to do more than just decode data, but to criticize and propose alternative interpretations, would not solve all the problematic issues related to the teaching, learning and uses of statistics. However, it could help citizens to analyze far more consciously the realities in which they live.

Even considering that statistical literacy is complex and is not restricted to the scope of content and technical procedures related to statistics, it cannot be denied that statistical literacy includes basic skills that may be used to understand statistical information or the results of research. Amongst these important skills are those related to data organization, construction and interpretation of different types of representations, and the understanding of concepts, vocabulary and symbols (Ben-Zvi, & Garfield, 2004).

Throughout the years, the GPEME has used Gal's model in its research studies because it addresses statistical literacy in a broader manner and because it aligns with a critical educational perspective (Freire, 1996) that links the need to undertake a critical analysis of the production, representation, dissemination and interpretation of statistical data.

However, a significant number of studies by GPEME explored the possibilities of using Gal's statistical literacy model in addition to its problematization with *reading contexts*, in research related mainly to *enquiry contexts* (Wild & Pfannkuch, 1999) and *school contexts* (Monteiro & Ainley, 2004).

The GPEME research studies, therefore, expanded the possibilities of using the Gal's model considering the specificities of Brazilian contexts. This article aims to discuss the aspects of statistical literacy that have been explored in GPEME studies, and in which teachers, who teach statistics, have participated. To achieve this objective, an analysis was conducted of publications by members of the GPEME since its creation in 2010, and that followed methodological procedures, which are not presented in the following section.

Methodology

A first methodological procedure to guide the analysis of previous GPEME studies was to formulate the following research questions: Which aspects of statistical literacy were explored in the GPEME studies, in which teachers who teach statistics participated? What possible contributions do these studies make for reflecting on teacher education situations that promote the statistical literacy of teachers?

The study corpus consisted of three types of publications by GPEME members: articles in periodical journals, papers in conference proceedings and book chapters published during the period from 2010 to 2020. These publications were identified by conducting searches in the curricula of GPEME researchers registered in the CNPq Lattes Platform (National Council for Scientific and Technological Development). These searches were guided by reading titles, abstracts and keywords, seeking to identify whether the publications addressed statistical literacy, and whether teachers had participated in the study. Reading the selected publications enabled the identification of three categories into which the publications were classified:

- *Studies on statistical literacy involving teachers from different schooling stages*: this category included articles and papers that explored aspects of statistical literacy amongst teachers who taught statistics for different groups of students.

- *Studies investigating aspects of the teacher's statistical literacy with the mediation of technologies*: this category included several publications related to studies that explored the potential of technological resources to promote the statistical literacy of teachers.

- *Studies on statistical literacy in situations of cooperative and collaborative teacher education*: this category included studies that explored the participation and role of teachers in promoting statistical literacy.

Although searches for the publications were associated with the production of the Brazilian members of the GPEME, it was identified that some publications were co-authored with researchers who are registered with the GPEME as international collaborators: Karen François (Vrije Universiteit Brussel - VUB, Belgium), Janet Ainley (University of Leicester, UK), Carolina Carvalho and Hélia Oliveira (University of Lisbon, Portugal), and Theodosia Prodromou (University of New England - UNE, Australia).

In the following sections, we present publications related to each of the abovementioned categories and discuss their contributions towards understanding and promoting situations in which teachers are able to develop their statistical literacy.

Studies on statistical literacy involving teachers from different stages of schooling

The Brazilian school system has been organized to meet the various different age groups and socio-cultural contexts of students. In general terms, basic education in Brazil is organized into the levels of early childhood education, primary education, and secondary education, with a youth and adult education (EJA) modality for those students who had been unable to attend school on a regular basis. In addition to this, so as to overcome the social inequalities that have resulted from historical processes since colonization, there are specific curricular schooling guidelines for indigenous peoples (Oliveira, Carvalho, Monteiro & François, 2018), for field populations (Souza & Monteiro, 2020) and for the remaining quilombo populations (Monteiro, Duarte, Carvalho, Almeida & Diniz, 2019). Another major challenge that needs to be overcome refers to the differences of schooling in urban and field contexts (Monteiro,

Leitão, & Asseker, 2009). In Brazil, *field education* is a prominent achievement of social organizations and movements, which, from the end of the 1980s, began to fight for good-quality, all-inclusive education, directed towards the knowledge of people living in rural areas (Monteiro, Carvalho, & François, 2014).

In the GPEME studies conducted in urban school contexts with teachers from the early years of primary school, we identified that, in general, teachers recognized the importance of inserting statistical topics into the school curriculum, despite possessing little knowledge on statistics and how to teach it. For example, teacher conceptions on teaching statistics are associated with the idea of processing information and most often on working with bar graphs (e.g. Santos, Carvalho, & Monteiro, 2010; Santos & Carvalho, 2014; Lira, Carvalho, Carvalho, & Monteiro, 2020). These studies highlighted the need for continuous education processes in order to contribute to practices that provide statistical literacy. Thus, the studies substantiate the perspective that the approach to statistical literacy is not spontaneously developed by teachers and requires planned, systematic continuous education processes that involve innovative methodologies centered on the role of teachers and students.

In research projects that investigated the teaching of statistics in *field education* contexts, it was also identified that teachers lack any continuing education to update and broaden their knowledge on statistics. Alcântara, Monteiro and Lima (2014) when analyzing a teacher education program for field teachers who teach statistics, observed that in a group of 124 teachers participating in the research, 75% reported that they had studied statistical content in their pre-service teacher education. However, of these, only 35% remembered any of the statistical topics that were studied or were able to list such content correctly in one of the items of a questionnaire that was applied.

Another challenge faced in the GPEME studies that addressed statistics education in the context of *field education*, was the need to integrate quotidian student socio-cultural knowledge. Thus, Alves and Monteiro (2011) identified that textbooks used in rural schools until 2012 did not present this integration of knowledge. The authors reported that these didactic resources only minimally addressed statistical content (approximately 2% of the total tasks), and either disregarded the social contexts of the rural areas

or approached them in a derogatory, prejudiced manner, for example, with stereotyped images of the population as peasants using ragged clothes and no shoes.

Medeiros and Lima (2019) also analyzed textbooks used in field schools for teaching mathematics and identified that tasks on statistical content presented no approaches aimed at statistical literacy and the field reality. When the authors identified any element that could be related to the field environment, it almost always served to illustrate the statements of the activities, with no problematization.

The GPEME studies in field education provided us with discussions on the need for a more in-depth theoretical and methodological stance on statistics education within these Brazilian social contexts, in order to favor the principles of valorizing local culture and knowledge within the scope of teaching and learning these curricular topics (François, Monteiro, Carvalho, & Vandendriessche, 2015). Thus, although the official recognition of field education as a national public policy has been a very significant achievement, implementing this policy in a manner that respects the principles for which it was created still remains a major challenge.

Furthermore, with regard to the specificities of urban school contexts, studies that addressed statistical literacy with teachers have also led us to reflect on the need to consider aspects that were unforeseen in the design of Gal's model. Thus, it is necessary to investigate and develop situations, tasks and activities related to statistical topics in teacher education, which are more explicitly linked to student socio-cultural aspects. For example, teaching statistics could problematize on the social practices of children and young people using smartphones, which are monitored by big data production mechanisms that generate statistics, which are then used for commercial purposes and to influence opinion and the consumption of large portions of students (François, Monteiro & Allo, 2020). Thus, approaches to teaching statistics may promote student awareness on practices such as these, enabling them to exercise their citizenship in a more critical manner.

Analyzing these studies related to the category that emphasizes the stages of schooling has also led us on to other reflections. Studies conducted by the GPEME suggest that the approach to the statistical literacy model with teachers also needs to consider the developmental stages of the students that they are

teaching, using different strategies that take into account the different ages of the students and their socio-cultural contexts.

Studies that investigate aspects of teacher statistical literacy with the mediation of technologies

A body of research involving teachers was conducted at the GPEME as a result of partnerships established with researchers from the University of Warwick and the University of Leicester in the UK. These studies investigated an active approach to data interpretation processes (Ainley, 1995; Pratt, 1995), which suggested that in activities that involve the representation of statistical data, primary attention should be given to the processes of interpretation (Ainley; Pratt; Nardi, 2001). *Active graphing* not only involves interpretation, but also the collecting, organizing, and systematizing data in tables and graphs, as well as analyzing these forms of data presentation. The perspective of *active graphing* emphasizes that the interactive use of computer programs may help to interpret and understand graphs. As well as providing other benefits, the use of software may also "save" time in other phases of the data handling process (e.g. collection and organization) so that more time may be spent on interpreting the data presented. The studies developed by the GPEME were conducted using the TinkerPlots software for teaching statistics during the first years of schooling (Konold & Miller, 2005). Until this moment, this software had been explored in studies, mainly in the US, Europe, Israel and Australia (Ben-Zvi, 2004; Bakker, Derry, Konold, 2006; Watson, Donne, 2009). The GPEME research was the first exploratory study of this software within Brazilian contexts.

Konold and Miller (2005) developed the TinkerPlots software, designed for students aged between 9 and 13, which offers tools for students to develop different data handling strategies. TinkerPlots has an interface that provides a dynamic approach, in which users need to interact with the software interface to explore different representations, which may vary according to the use of available functions. In the present article, we only mention the research studies which explored the use of TinkerPlots by teachers from a variety of school contexts and that investigated the influence of specific aspects.

Martins and Monteiro (2010) analyzed whether the creation of a database with TinkerPlots would assist in the interpretations of data made by teachers. The study was developed through semi-structured interviews with four teachers from the early years of primary school. Two of the participants built a database to answer three questions, and the others received the ready-made database to answer the same questions. The analyzes of the interpretations and reflections developed by the teachers indicated that their knowledge of statistics until the moment of the research did not seem to enable the necessary reflections for the teaching activity with regard to teaching statistics. In terms of the role of constructing the database as a resource in the interpretation process, the research results suggested that the software used could not in itself be considered as a facilitator for teacher interpretation. However, the fact that TinkerPlots possesses tools that cause the subject to engage in interpretation, would seem to be an instrument that facilitates the understanding of the various elements contained within the graphs and, consequently, helps to understand statistical concepts and interpretation strategies.

Asseker, Monteiro and Lima (2013) investigated the use of the TinkerPlots software by teachers to explore data and build representations using specific software tools. The study was conducted with teachers from field schools in a municipality in the Agreste region of the state of Pernambuco. In a first research session, the participant profile was identified, in terms of computer use and teaching statistics, and familiarization activities were performed with the software so that the teachers could understand and experience how to use its tools. In the second session, the teachers answered questions related to a database based on the perspective of the bivariate context or of cross-referencing two variables. The research situations were constituted in the value propositions of cross referencing: between quantitative variables, between qualitative variables and between quantitative and qualitative variables. In general terms, the teachers demonstrated facility in handling the software tools. They were able to plot through several actions, such as: organizing the categories in horizontal and vertical axes; inserting scales; stacking; ordering; using features of color and gradient. On many occasions, this manipulation brought about a change in the reflection and a contribution towards the interpretation. Thus, the software tools

were used to construct different representations at the moment of exploring the data, which enabled greater interaction with the data, offering different clues in the construction of the answer.

Martins, Monteiro and Queiroz (2013) investigated how a field school teacher understood sampling when using the TinkerPlots software. In Brazil, teachers in the early years of primary school teach all school subjects. Exploring this aspect, the study sought to identify the teacher's understanding of three basic elements of the sampling concept: size, type and representativeness. The study also examined how the TinkerPlots tools influenced the understanding of these three aspects. The teacher attended a session with an initial interview regarding the concept of sampling; a session in which the software was presented; performed two sampling activities on TinkerPlots; and lastly took part in an interview that aimed to identify any possible changes in the understanding of the concept of sampling. It was observed that the teacher revealed changes in her understanding of size and representativeness in some samples. From simulations using the TinkerPlots tools, she was able to identify sizes and registered concern about bias in small samples. The analyzes suggested that the sampling activities developed with this software facilitated understanding with regards to sampling.

Discussing the research data with TinkerPlots made it possible for the complexity of using educational software to be observed from a broader viewpoint, insofar as its proposition consisted of a motivation factor for working with statistical topics. One resulting problematization was related to recognizing that teachers should base the data interpretation process on an active, participatory perspective. Monteiro and Martins (2016) suggested that continuing education processes could contribute to developing the role of teachers by helping them to use more innovative methodologies, such as those involving the use of the computer.

Studies with TinkerPlots have also motivated reflections with researchers from other countries. Martins, Monteiro and Prodromou (2017) developed analyzes related to teachers' interpretations when using TinkerPlots as being an important element in that it expands the possibilities of situations in which in-service teachers are able to learn how to improve their own statistical literacy as well as that of their students. Within the scope of the discussion, the concept of sampling seemed to be crucial for

understanding the statistical data. However, this topic is generally not emphasized in the school curriculum or on teacher education programs. The authors discussed a study on how teachers in the early years understood issues of sample size and representativeness using a more advanced version of the TinkerPlots software. The participants were four Brazilian public school teachers. The research protocol followed three phases: interviews to identify the teacher profile and statistical knowledge; a familiarization session with TinkerPlots; and a session using the software to solve tasks that involved sampling. The results demonstrated that teachers began to consider aspects of data variation to determine when representative samples were presented using TinkerPlots. The ability to select samples and analyze them seemed to contribute to improving their understanding of sample size and representativeness. As the aim of the study was to explore teacher education activities that supported the development of aspects of statistical literacy, further analysis of the study results offered insights into task design for helping teachers to teach sampling as part of statistical literacy. For example, the analysis suggested that the questions asked during the research sections should not only explore the knowledge of the participants on sample size or level of confidence, but also promote reflection on the meanings attributed to the tasks, thereby leading to a discussion on the skills needed for statistical literacy in the big data era (François, Monteiro, Allo, 2020).

Carvalho, Martins and Monteiro (2017) argued that studies related to teachers understanding statistical concepts through the mediation of TinkerPlots served to highlight the possibilities of using technological resources as a teaching context in which the frequency and types of feedback are expanded in order to encourage the learning of statistics. The reflections indicated that when teachers have the opportunity to explore contexts in which these tools are used, they also develop knowledge and skills that give them confidence to implement them in their classrooms.

Hence, not only teachers, but managers need to broaden their conceptions concerning resources and the use of technology in the teaching of statistics. For example, Monte and Carvalho (2018) conducted a mapping study of 23 Reference Secondary Schools in the city of Recife, in 2017, with the aim of identifying teaching actions or projects approach tables and graphs with the aid of a computer. Twenty

managers took part, plus three pedagogic coordinators who, at the time, were standing in for managers on vacation. Participants answered a questionnaire made up of closed and open questions. The results indicated that while the managers were aware of the work with statistics education in schools, they reported having no knowledge on the existence of projects involving the use of computers for this purpose. According to the participants, computers in these schools would essentially be used for administrative tasks.

Exploring the possibilities of technologies such as messaging applications for in-service teachers who teach statistics is the object of study for Oliveira, Carvalho, Monteiro and Carvalho (2020). These apps represent a manner with which to share and expand knowledge on teaching and learning statistics as an M-learning tool. The results indicated that the participating teachers frequently used the WhatsApp application, which could assist in discussions and in the development of educational activities in school and out-of-school contexts.

The results arising from studies with teachers and using technological resources have led us to important reflections on the teaching and learning processes of statistics in different school contexts. A first aspect to be considered refers to the importance of teacher mediation in the use of technologies as educational software, deconstructing arguments from common sense and company discourses on the supposed power of technology in facilitating the teaching and learning of statistics. Moreover, these studies were important learning opportunities for the GPEME researchers and students because they were challenged to broaden the international literature, since there was no specific national literature. The different studies also made it possible to explore and build different variations for the methods of collecting and analyzing data for each context and participant profile, and although this forced the research team to exert a much greater effort, it proved to be extremely important for our growth as researchers.

Studies on statistical literacy in teacher education situations with a cooperative, collaborative approach

More recently, GPEME research has not only begun to diagnose or investigate the understanding of teacher literacy, but has also proposed to explore teacher education processes that may incorporate the role of teachers in learning in a collaborative situation and their cooperative attitudes in helping colleagues to develop statistical literacy.

One of the first GPEME studies to explore a teacher education situation, and that focused on aspects of statistical literacy was conducted by Carvalho (2015). The teacher education workshop involved 18 teachers from Youth and Adult Education (EJA), participants from a course that focused on EJA and social inclusion promoted by the Center for Teaching, Research and Extension in Youth and Adult Education and Popular Education (Nupep) at UFPE. The participating teachers, from different municipalities in the state of Pernambuco, were asked to experience some stages of the investigative cycle. Organized into three groups, they problematized the stages of an investigative cycle in statistics (Wild & Pfannkuch, 1999) and were challenged to initiate the process by formulating a research question. Each group proposed a theme for investigation: dropout rate from the EJA course; continuing studies after the teacher education course; the ages of the EJA students taught by the participating teachers. The work developed was linked to a context from the reality of the participants, and that made sense to them. The teachers collected the data, and later organized and analyzed it, and produced representations in the form of graphs and prepared the results for the other work groups. The reflections that arose from the data obtained and presented, were then expanded and considered from the viewpoint of the participants' didactic work methods with their EJA students, thereby helping to rethink the pedagogic practice. Furthermore, these reflections were directed towards the life trajectories of the participating teachers and to the limits and possibilities of their original communities in providing opportunities for their participation in continuing education processes.

From the perspective of the work involving collaborative education, a survey was conducted that investigated the development of statistical literacy amongst teachers in indigenous schools for the Xukuru do Ororubá people (Oliveira, Carvalho, Monteiro, & François, 2018). The investigation aimed to analyze the possibilities of promoting statistical literacy in an intercultural context, to support the teaching

procedures and to stimulate mathematical knowledge amongst the students through reflective practices. We analyzed whether and how statistical content was worked on by teachers from the early years in the Xukuru schools, and together with the teachers, we planned and developed classroom activities involving the stages of the investigative cycle in statistics (Wild & Pfannkuch, 1999) within a collaborative group. We employed participant observation, semi-structured interviews with three indigenous teachers, documentary analysis of the class diaries of two teachers and the formation of a collaborative group with the participation of eleven teachers from the early years of primary school. It was observed that teachers from this ethnic group conducted very few school activities involving statistics. The collaborative work contributed to the discussion on statistical concepts, from the perspective of statistical literacy and its importance in investigating and understanding the local reality of the peoples. The group of teachers planned a teaching project that involved experiencing the stages of the investigative cycle, using, as a common theme, the water resources of communities in the indigenous territory. Within the school environments, children, alongside their teachers, collected data from other indigenous residents and addressed not only quantitative aspects, but the social practices of water use and pollution, and a history of how their ancestors took care of the water sources and the religious relationship that they maintained with water. The stages of the investigative cycle in statistics were addressed by the teachers in an interdisciplinary manner.

Costa Júnior, Monteiro, Carvalho, Eugênio and François (2020) discussed a study that investigated the possibilities of developing statistical literacy in initial teacher education. Nine students participated from the undergraduate degree course in mathematics from a public university in Northeastern Brazil. The research design included semi-structured individual interviews and seven meetings with the group of participants. The interviews and meetings were filmed. A verbatim transcription was made of the data collected from the interviews. The qualitative content analysis of the protocols was based on an interpretive approach. Analysis of the participant interviews suggested that the undergraduate students experienced difficulties in developing more elaborate interpretations due to their lack of understanding mathematical and statistical concepts. As part of the research, a teacher education group was developed

based on dialogical interactions that enabled cooperative approaches, which also facilitated the participants in improving their ability to reflect critically on statistical data and their perspective on statistical literacy.

Eugênio, Monteiro, Carvalho, Costa Junior and François (2020), addressed another study that investigated aspects of continuing teacher education from the perspective of statistical and probabilistic literacy in the context of teacher education meetings held in a collaborative manner. Teachers who teach statistics came to realize the importance of probabilistic literacy in decision making and for critical citizenship. The results suggested that an important strategy in the teacher education meetings was to raise different arguments and questions, problematizing teacher responses. Data analysis suggested that the questioning approach, based on dialogical processes with teachers, is able to promote reflections on the concepts of probability and on how to adopt a critical approach when teaching these concepts.

Lira & Carvalho (2020) analyzed aspects of the creative insubordination of early childhood education teachers in relation to how they conceived and included statistical activities in their planning and experiences with children. According to the authors, based on D'Ambrosio & Lopes (2015), the creatively insubordinate teacher constantly needs to make decisions, and in most cases, this requires assuming postures and creating new work dynamics that stand in opposition to what is established either by professional routine or by legal guidelines. From this perspective, teachers should not only limit their practice to previously determined objectives, but rather consider the context into which their students have been inserted. A semi-structured interview was conducted with three teachers from a municipal early childhood education center who had recently received textbooks to use with children aged from 4 to 5 years. Although the interviews revealed that these teachers possessed little knowledge on statistics, despite this reality, they reported that they approached statistics by employing graphical tasks in the classes with the children. The authors assessed this teacher attitude as being evidence of an act of creative insubordination in the teaching of statistics in early childhood education. The study also highlighted the need for continuous teacher education on how to address the first notions of statistics with young children.

Souza and Monteiro (2020) explored the development of statistical literacy amongst teachers in field schools in the *Zona da Mata* region of Pernambuco. In addition to statistical knowledge, teachers in field schools also need to be challenged into considering the contexts of rural education and their specificities. The study analyzed the manner in which teachers in rural areas understood graphs based on interviews and continuing education workshops on statistical literacy. The results obtained from the interviews demonstrated that gaps existed in relation to the conceptions of field education, and also that there were difficulties with regard to understanding the graphs proposed for interpretation. The workshops proved to be important spaces for cooperation and education in terms of statistical literacy, since the teachers felt open to recognizing their need to learn about statistics and of being encouraged to improve their pedagogic practice.

These studies on teacher education have indicated links, from the perspective of the investigative cycle (Wild & Pfannkuch, 1999), with developing the dimensions of statistical literacy proposed by Gal (2002), thereby constituting an important strategy for developing research on teacher education considering the Brazilian context.

Final considerations

This review of studies developed by GPEME since 2010, involving teachers and the approach based on the statistical literacy model by Gal (2002), has enabled a number of reflections on the contributions provided by this body of research. One initial contribution of these GPEME studies was the exploration of situations that were able to promote teacher education that encouraged teachers to understand statistical content from the perspective of statistical literacy. Thus, it was necessary to adapt the general character of the adult statistical literacy model, for an approach towards teachers who teach statistics, and who, therefore, in addition to developing their own statistical literacy, would need to be concerned with promoting the statistical literacy of their students.

Another contribution of the GPEME research was to reflect on the adequacy of the Gal's model for teaching statistics for different educational levels and not only for adults. The research addressed aspects

of statistical literacy in the teaching and learning of statistics from young children in early childhood education, through young and older people in youth and adult education, who have returned to school after many life experiences.

The GPEME studies have also served to develop reflections on the possibilities of developing statistical literacy within the context of situations mediated by digital technologies, particularly highlighting studies with TinkerPlots, which have been pioneering in Brazilian statistics education contexts. One important aspect of this body of research is related to the importance of teacher mediation and to the types of feedback for promoting active teaching and learning processes in statistics.

The studies that have investigated cooperative and collaborative approaches to teacher education suggest that the core of these situations that effectively promote statistical literacy are those is which the leading role of teachers is emphasized in collective learning. The research has contributed to broadening the understanding of statistical literacy based on the Gal' model, involving aspects of knowledge, a critical posture and teacher attitudes.

The ongoing studies at GPEME also have the potential to expand the possibilities of statistical literacy both in different socio-cultural contexts specific to Brazil, as well as in social practices influenced by global phenomena, such as the production of big data (François, Monteiro, & Allo, 2020) and school education contexts in times of pandemics, such as Covid 19, which has required new pedagogic approaches, as for instance with online teaching (Carvalho, 2020). These social situations have presented authentic, challenging contexts in which the development of statistical literacy may be promoted through the use of real data.

One important aspect that should continue to be emphasized in GPEME research is the search for a greater understanding of how to develop the elements related to the critical posture and attitudes that constitute statistical literacy, both in teachers and in their students. These studies may expand the possibilities of statistical literacy to promote more effective citizen participation, especially in a society attacked by the dissemination of increasingly more media misinformation.

Acknowledgements

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