

**Knowledge developed by Brazilian teachers from a  
collaborative training in statistics**

**Conhecimentos desenvolvidos por professores brasileiros  
a partir de uma formação colaborativa em Estatística**

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**ABSTRACT**

This article aims to analyze the narratives of two Brazilian teachers, who work in Elementary Education, based on their participation in a collaborative teacher education in statistics, for professional development. This is a qualitative research, which uses audio and video recordings during training, planning, practical actions and reflective sessions. The data were analyzed using the content analysis techniques. When comparing knowledge before and after training, it was possible to verify that the teachers developed learning related to statistical content and pedagogical practice to teach statistics. Understanding, experiencing and reflecting on the PPDAC investigative cycle contributed to the

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development of statistical literacy. The teachers recognized the benefits of exploring real contexts, and actively engaging students, as opposed to traditional approaches. The teacher education methodology promoted reflective processes on practice, the co-production of knowledge and professional development. This study highlights the positive impact of collaborative training on the pedagogical practices of statistics teachers.

**KEYWORDS:** Training. Statistics Teaching. Meaningful Learning.

## RESUMO

Este artigo tem como objetivo analisar as narrativas de duas professoras brasileiras, que atuam no Ensino Fundamental, a partir de participação de formação colaborativa de Estatística, para o desenvolvimento profissional. Esta é uma pesquisa qualitativa, que utiliza áudio e vídeo gravados durante a formação, planejamento, ações práticas e sessão reflexiva. Os dados foram analisados pela técnica de análise de conteúdo. Ao comparar os conhecimentos antes e após a formação, foi possível constatar que as professoras desenvolveram aprendizagens relacionadas ao conteúdo de estatística e à prática pedagógica para ensinar estatística. Compreender, vivenciar e refletir sobre o ciclo investigativo PPDAC contribuiu para o desenvolvimento do Letramento Estatístico. As professoras reconheceram os benefícios de explorar contextos reais e envolver os estudantes ativamente, em oposição às abordagens tradicionais. A metodologia de formação promoveu processos reflexivos sobre a prática, coprodução de conhecimento e Desenvolvimento Profissional. Este estudo destaca o impacto positivo do trabalho colaborativo nas práticas pedagógicas dos professores de estatística.

**PALAVRAS-CHAVE:** Formação. Ensino de Estatística. Aprendizagem Significativa.

## 1. Introduction

Mathematics is a discipline that is present in all school curricula. Despite this, in general, teachers lack knowledge on how to teach mathematics, especially and specifically on how to teach statistics and probability (Hahn, 2015; Pontes; Castro, 2021; Nacarato; Mengali; Passos, 2017). Specifically, teaching statistics and probability requires the use of autonomous activities, that is, activities that simulate real situations (Palm, 2007; Pontes; Castro, 2021), with numbers in contexts and not the use of decontextualized, mechanical exercises that only involve the application of formulas, as can be seen in different teaching contexts (Hahn, 2015; Pontes; Castro, 2021; Santana; Cazorla, 2020). For teaching statistics, teachers need to know various possibilities, which requires research and professional improvement on the subject.

In Brazil, initial teacher education courses in pedagogy provide prospective teachers with a basic understanding of mathematical precepts, which leaves many with little prior exposure to the subject. This lack may raise conceptual and methodological doubts, requiring these professionals to seek continuing education or training courses to overcome their difficulties (Nacarato; Mengali; Passos, 2017).

Gatti (2008) explains that continuing teacher education involves participating in study groups, specialization and extension courses, and collaborative formative courses organized among graduates, postgraduates, or students attending a certain level of schooling. One of the most prominent modalities of teacher continuing

education is collaborative training, which is a formative proposal aimed at exchanging knowledge among participants, improving knowledge related to the conceptual and pedagogical field and exploring the existing innovations in the expertise of the professionals involved (Ponte, 1996).

Some authors (Castro-Filho *et al.*, 2022; Ferreira, 2006; Ponte, 1996; Boa Vida; Ponte, 2002) have been studying collaborative work among teachers who teach mathematics. According to them, during the process, participants had the opportunity to share knowledge and experiences and gained elements that could enhance teachers' professional development. This development occurs from the inside out, involving the teacher in the cognitive, affective and relational aspects. It can happen outside of and inside formative processes, taking place through reflection, action, and new reflection. In this process, knowledge can be exchanged, whether in teaching or non-teaching practices. Aiming for professional growth, which happens as the teacher becomes able to conduct teaching adapted to students' needs and interests and to contribute to their improvement and that of educational institutions (Ponte, 1998).

Considering the professional development of teachers within a training process, the following question arises: What reflections and learning can pedagogy teachers develop in the process of collaborative teacher education in statistics? How does this contribute to the professional development of these teachers?

From this perspective, the present study aims to analyze the narratives of two Brazilian teachers, with a degree in pedagogy, collected from a collaborative teacher education in statistics. The teachers were chosen for convenience, as they were available to participate in professional development training.

The importance of this study is justified because we believe it to be relevant to present to the public the contributions of a formative process for the teaching practice of teachers who teach mathematics. The results obtained in a collaborative teacher education in Brazil can complement the international academic literature, making it possible to contemplate conceptual and methodological aspects, as well as cultural and social ones. The next section presents a brief discussion on collaborative teacher education: concepts and perspectives.

## **2. A brief discussion on collaborative training: concept and perspectives**

To work on the concept of collaborative teacher education, it is necessary to understand that not every situation involving people working together can be considered collaborative work (Boa Vida; Ponte, 2002). Collaborative work happens when a team composed of teachers, professors and undergraduate students, among

others, participate democratically in the group's decisions, amid mutual help based on equality between those involved, without any type of hierarchical relationship.

Some authors (Castro-Filho *et al.*, 2022; Ferreira, 2006; Ponte, 1996) believe that the partnership between university and school carried out through collaborative training is a favorable path for advances in mathematics teaching. This is because both in-service teachers who work at any level of education or prospective teachers can contribute in some way, because of their joint work, to the development of teaching practices that will be later applied in educational institutions.

The school space has been considered a privileged locus of teacher education, so the collective work emerges as an instance of reflection and research for the teacher. Although Brazilian schools have a strongly individualistic culture, collaborative training has made it possible to modify this culture, favoring the visualization of scenarios present in the organizational totality of the school, and its systemic character (Fullan; Hargreaves, 2000). It is necessary to understand that each institution experiences different social contexts and that some of the problems will have solutions anchored in the field of practice, marked by the uncertainty and complexity of these contexts, therefore, it is not possible to have previously learned answers for all situations.

Collaborative work only becomes an advantageous process if teachers share a common goal. On this issue, Ferreira (2006) says that each professional needs to be aware that the theory seen in any activity that aims to train teachers is not transmitted in a decontextualized or fragmented way. Moreover, the activity should not be carried out without considering the professionals' objectives and context, and the need to explore the steps to be taken during the teaching process. Thus, it is necessary that during collaborative training, teaching sequences, methodological proposals and established dialogues are developed considering the peculiarities of the group (Ferreira, 2006). It is vital to reflect on adaptations that must be made during the suggested activities, to adapt them to each reality. To this end, it is necessary to observe the needs of the professionals involved so that theory and practice go together, considering the working conditions and target audience.

Another important aspect that emerges in collaborative relationships is reflective practices (Ponte, 1996). It is important that, alongside the activities developed by the participants of collaborative training, members reflect on how their classes are being conducted, so that each professional seeks to analyze their own actions. Clarke and Hollingsworth (2002) present a model to describe the process of professional



development that can occur during training, whose structure allows for analyzing this process in four stages: external domain (information and stimulus from the environment); the domain of practice (application of what was seen in classroom training); mastery of consequence (student learning); and personal domain (teacher's knowledge, beliefs, and attitudes).

Clarke and Hollingsworth's (2002) model is based on the teacher's reflection, as it enables the teacher to learn new things and implement changes to foster improvements during their interventions in the classroom. However, for this, it is necessary to be open to changes, which are manifested in the subjects' ability to remake themselves with regard to building and deconstructing personal beliefs and convictions about the teaching and learning processes (Ferreira, 2006).

In collaborative work, in addition to exchanging knowledge and experiences, one of the elements that also contributes to professional development is carrying out work that points to reflective practices based on examples of teaching intervention (Ponte, 1996). Castro-Filho *et al.* (2022) conducted a collaborative mathematics training, focusing on statistics, with 28 Brazilian teachers who taught in Elementary School. The training was carried out in the context of a university-school partnership through an online professional learning community – PLC, involving teachers from eight public schools and a researcher from eight public universities in three different states in the Northeast and one in the Southeast of Brazil. The process was based on a collaborative perspective, distributed in four modules: statistical concepts, equity at school, investigative cycle, and reflections on the investigative cycle. As advocated by Ferreira (2006) and Pontes (1996), the exchange between all participants, including undergraduate students and professors, enabled reflections on conceptual and methodological issues for teaching statistics.

Hence, the groups must be committed so that there is an exchange of experiences, opinions, and knowledge. Moreover, among the different views, each participant must respect the other. The action of reflecting together on the class taught by one of the members of the group can help the teacher to understand, for example, the aspects that are going well, as well as those that need to be better developed, pointing out possible weaknesses. This dynamic can be facilitated with reflective sessions, as it helps in self-reflection on their teaching practice (Santos, 2011). Magalhães (2007) sees the reflective session as a space for the construction of a critical and reflective professional in education, in which two or more participants reflect on a completed class so that each participant guides the other through the critical

reflection of their actions with the aim of mutual help, which benefits all. When teachers reflect on their practice, they end up adopting new approaches to working with their students, as they begin to see weaknesses and remedy them, enhance competence, and develop professionally.

We can conclude from the above that when collaborative training has a common objective, it provides significant gains for the professionals involved, as it allows the emergence of reflections on teaching in general. Therefore, during collaborative activities, everyone benefits, since they are collectively producing means for their participants' professional development. Next, we will discuss meaningful learning from David Ausubel's perspective.

### **3. Meaningful learning from David Ausubel's perspective**

The meaningful learning theory was created by David Ausubel in 1963, who states that the concept of meaningful learning is characterized by the interaction between the individuals' prior knowledge and new knowledge acquired at a given moment in their lives. Ausubel (1963) argues that this interaction is non-literal and non-arbitrary and clarifies that non-arbitrary evidence indicates relevant knowledge already present in the cognitive structure of the individual who learns. In the Meaningful Learning Theory (MLT), Ausubel investigates and describes the process of cognition from a constructivist perspective.

Moreira (2012) believes that in Ausubel's Meaningful Learning Theory, new knowledge brings to the individual a specific meaning where a priori knowledge ends up generating new meanings, leading to higher cognitive stability so that the learner expands and updates previous information. From this perspective, Ausubel (2003) thinks that learning is meaningful when the ideas expressed symbolically interact in a given cognitive process so that what has been learned becomes permanent and generates a meaning for those who learn. In other words, it is not a passing knowledge.

Mechanical learning happens when the content to be learned cannot be linked to something that the individual has already learned before (Ausubel, 1993). In this context, the newly acquired information is learned without interacting with concepts in the cognitive structure. When learning occurs mechanically, it is passing learning. For example, when the subject manages to memorize formulas, phrases, and excerpts for a purpose, as happens today among students in final exams.

Pelizzari *et al.* (2002) state that for meaningful learning to occur, following the assumptions of David Ausubel, individuals must be willing to learn. Moreover, the content to be learned must mean something to the individual who learns, based on the

principle that each person selects content that means something to them insofar as they relate it to previous knowledge.

Thus, this model is conducive to meaningful learning because, according to Ausubel, learning is meaningful when the individual actively participates in the search for knowledge, through the development of a self-discovery activity, which guides their personal search with regard to the acquisition of knowledge, so that the acquired knowledge is not a repetition or copy of the teachings of the book or the teacher, but a personal reworking (Ausubel, 2003). The methodological procedures of the investigation will be presented below.

#### **4. Methodological investigation procedures**

This research was part of the first author's master's research within the research project "Desenvolvimento profissional de professores que ensinam Matemática" (D-Estat) [Professional development of teachers who teach mathematics], registered with the Certificate of Presentation of Ethical Appreciation (CAAE) with number: 26229119.1.1001.5526, whose proponent institution was the State University of Santa Cruz - BA. D-Estat is a group composed of researchers and institutions from different Brazilian states: Bahia, Ceará, Rio Grande do Norte, Pernambuco, and São Paulo. They comprise the Mathematics Education Northeast Network (REM-NE)<sup>4</sup> which aims to promote studies and research in mathematics education, stimulating academic production and the formation of resources through the articulation between the three academic levels, basic and higher education, and postgraduate studies.

Collaborative teacher education took place at the school itself, at a time defined by teachers and administrators. The researchers stayed one day a week, for two hours, after working hours, to participate in the discussions. It should be clarified that the university has been working together with this school, in a collaborative way, for about 10 years, with teacher education meetings that addressed the interests and needs of teachers and managers. Participation in the meetings was voluntary. The program included conceptual and methodological discussions for teaching statistics. From these reflections, the teachers collaboratively developed three teaching sequences that explored statistics. Nine teachers participated in the process, the principal, the school's pedagogical coordinator, three professors, four master's students, and four undergraduate students.

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<sup>4</sup> Available in: [https://www.instagram.com/rem\\_nordeste/](https://www.instagram.com/rem_nordeste/)

The narrative analyses were carried out through a reflective session, with two teachers who collaboratively constructed the teaching sequence for their classes. The reflective session was guided by 17 semi-structured questions that addressed beliefs and attitudes related to statistics and teaching practice, contributions and challenges of collaborative teacher education, learning about statistics and methodological approaches to teaching and possible changes in the pedagogical practice of these teachers. In this article, to meet the defined objective, the narratives of nine of these questions were analyzed.

In this research these teachers were characterized as Teacher A and Teacher B, for ethical and anonymity reasons. The choice of teachers was based on interest and availability in taking part in the teacher education for professional development and monitoring of planned classes, therefore, it was a choice based on convenience. Teacher A has a degree in literature with 30 years of teaching experience in basic education. She currently teaches science, mathematics, and arts. Teacher B has a pedagogy degree, with ten years of experience as a teacher. She currently teaches history, geography, and religion.

During the formation course, we introduced the methodological approach Problem, Planning, Data, Analysis, and Conclusion (PPDAC), developed by Wild and Pfannkuch (1999), as it is a methodological approach used to conduct investigations and solve problems in teaching statistics. This cycle is made up of five stages: 1) Problem, which involves identifying which question gave rise to the research, this definition is what will guide the identification of the research objective; 2) Planning, dedicated to the development of a detailed research plan, with the choice of the most appropriate method and technique for carrying out the investigation; 3) Data, the stage in which data collection occurs; 4) Analysis, which involves the processing and interpretation of collected data, which can be done through statistical and visual tools, such as graphs and tables, helping to identify patterns and trends; 5) Conclusion, where the researcher summarizes the research findings and reflects on their implications.

The PPDAC was inserted in teaching sequences planned collaboratively by teachers and students. Teachers and students jointly developed a survey in a 5th-grade class to find out which style and author of comics (HQs) was preferred by students in the 3<sup>rd</sup>, 4<sup>th</sup>, and 5<sup>th</sup> grades of the research school. The topic was suggested by one of the children who remembered recently participating in a comic book seminar at school, and it was accepted by other classmates in the classroom. The 5<sup>th</sup> graders



created a survey instrument and went to the other classes asking questions. They also answered the poll. Finally, the group counted the votes, created hypotheses about the result, analyzed the data, created graphs, and drew conclusions.

During the formation, we surveyed the participants, and collected and analyzed the data jointly. In one of the tasks, the teachers were asked to apply the PPDAC, a methodology for teaching statistics, in their classes and bring the data and reports to debate with the researchers. After obtaining the data in a collaborative way, we held a reflective session to understand the participants' learning and view of this process. The reflections were based on the Reflection, Planning, Action, Reflection (RePaRe) spiral, which is a teacher training methodology, guided by reflection in and about practice, enhanced by a process with collaborative dimensions (Magina *et al.* 2018). This methodology was followed in the collaborative teacher education and in monitoring the teachers' plans. The RePaRe spiral provided a reflective process on the practice. According to Magina *et al.* (2018), training based on the RePaRe spiral translates into an activity of co-production of knowledge, training, reflection on practice and professional development. The teachers commented that the activities developed in the formation based on the RePaRe spiral (training methodology) helped them reflect on the actions they developed with the class during the experience of the PPDAC (methodology for teaching statistics) and, even after completing the formative process, they could continue planning, applying, and reflecting upon their actions in the classroom.

The research methodology was the case study, which, according to Gil (2016), is a research technique that analyzes a current phenomenon in its real context, and the variables that influence it. It is a systematic study that allows examining complex phenomena of an institution, individual or group of individuals. It is important to point out that the purpose of the case study is to produce knowledge about a phenomenon.

Content analysis was used as a data analysis technique, with the aim of identifying underlying themes, patterns, and meanings. It is an iterative process that includes coding, categorization, and interpretation steps, allowing for a deeper understanding of the data. Content analysis is widely used in several areas of study, such as social sciences, psychology, communication, and education (Bardin, 2011). After that, we detail the research presented through the analyses and discussions.

## **5. Analyses and Discussions**

The results presented here underwent: 1) pre-analysis; 2) categorization or coding; and 3) treatment of results, inferences and interpretation, according to Bardin

(2011). The results will be discussed in three sections: 1. Prior knowledge and knowledge acquired after the training; 2. Relationship between Ausubel's theory and the teachers' pedagogical planning 3. Activities tackled during the training that favor meaningful learning.

### **5.1 Prior knowledge and knowledge acquired after the training**

The teachers revealed that the training and the experience in the training helped them acquire knowledge of statistics that they did not use in their routine and during mathematics classes. This perception is important, as it shows that training filled gaps that will help in teaching practice, by mobilizing the knowledge needed to teach statistics. At the personal or individual level of each teacher, they will be able to use the conceptual knowledge of statistics and change their attitudes towards teaching, which enables the professional development of these teachers (Day, 2011).

One example was the exploration of measures of central tendency, the teachers emphasized that this knowledge was acquired through the collaborative teacher education. Although this knowledge is not present in the National Common Curricular Base, a document that standardizes the elementary school mathematics curriculum in Brazil, the ideas of average, for example, can be explored through division situations, being an important and necessary knowledge for the elementary school (Brasil, 2018). However, the teachers did not explore concepts related to the measure of central tendency, because they did not have full conceptual knowledge and because they thought they were very difficult concepts for children. This perception can be modified through collaborative teacher education.

In this view, Lopes (2008) considers it fundamental for the professionals who will teach statistics to receive education that allows them to critically interpret and evaluate the statistical information received and communicate and discuss that information. In this way, teachers feel more confident about the subject and may be able to explain it better in the classroom. In the interview, both teachers affirmed that the training clarified doubts and provided, in a very beneficial way, the overcoming of some gaps they had in relation to the statistics content:

During my degree course, I did not have a subject that would help me deepen the content of statistics. Another difficulty is that the books only show graphs and simple tables, and most of the time they are just bar graphs, they were the only ones I saw in the books. Today I know what a line graph and an area graph are, and I learned to build them. Before, I didn't know which graph to use to represent the data of a study; now, it's clearer in my head. I also learned to distinguish between mean,

mode, and median. Before the training course, I only knew what mean was (Teacher A).

As a pedagogy student, I didn't attend a subject that was related to statistics teaching. The most advantageous aspect of the training was that I learned the PPDAC methodology approach. I used to only work on statistics through the activities of the textbook in a very superficial way, today, I know that I can do a survey with my students, so that they can create a problem, collect, and analyze their research data (Teacher B).

We can see in the teachers' statements, the non-inclusion of teaching statistics in some degree courses, as mentioned in the research by Pontes and Castro (2020) when analyzing the conceptual and methodological knowledge of teachers who work in the early years of elementary school. The lack of statistical knowledge of teachers can make them not teach statistical concepts or teach in a restricted and superficial way, only based on what is in the textbook. Similarly, the lack of methodological knowledge, such as the experience of investigative cycles (Wild; Pfannkuch, 1999), makes teachers not propose the use of real situations and data, which compromises the development of critical and statistical thinking, present in Statistical Literacy conceptualized by Gal (2002).

Throughout the discussions proposed in the collaborative training, the teachers realized that focusing only on the textbook could bring difficulties in relation to the content. They understood, for example, that the statistical content explained in the textbooks adopted by the school explored statistics superficially, as they provided ready-made data, so that students only answered only simple questions and were not encouraged to think or build tables and representations of graphs. Therefore, they needed to bring proposals to fill these gaps.

During the reflective session, when watching the footage of the class that showed the application of the teaching sequence collaboratively elaborated by the teachers based on the PPDAC investigative cycle (Wild; Pfannkuch, 1999), the teachers began to rethink actions related to the teaching of statistics, which they thought they could have developed, comparing the knowledge of before with that of the reflection time, as can be seen in the following protocols:

After this reflection, I believe that next year, I will not only use the textbook, but I will have other options. I'm not going to let students just interpret a ready-made graph, I'm going to use the PPDAC cycle when the book suggests it or I want to suggest a survey. In this way, meaningful learning can happen for students. I'm also going to change some practices that I realized I did wrong this year (Teacher A).

By reflecting on the entire training process, right up to the execution of the teaching sequence, I could see how much I learned. I reflected on the whole process, even during this conversation, it crossed my mind

how much we need to mature in relation to our practices. I realized how much I need to study. And seeing how the teaching sequence was done, I noticed some problems that appeared, and when I do it again, I won't make the same mistakes and I will improve the execution (Teacher B).

Teachers A and B's speeches show the reflection made on the practice developed in a collaborative way and how the knowledge developed throughout the training, from theoretical-practical actions, such as the planning and application of a teaching sequence based on the investigative cycle of the PPDAC, may help with other teaching sequences with statistics in the future. These reflections on practice and actions in the classroom bring beliefs, attitudes, and knowledge about practice and the school context, necessary for the Professional Development of teachers (Castro-Filho *et al.*, 2022; Clarke; Hollingsworth, 2002). We emphasize that, despite the reflection shown in the protocol being individual, it also happened collectively.

The teachers perceived that the learning acquired with the PPDAC is only complete when the student can experience it in its entirety, as each phase adds new knowledge to the student. This finding, at the end of the process, is shown as an acquired contribution to the teachers' practice (Clarke; Hollingsworth, 2002). Considering teachers' contribution during the training, the following comments can be highlighted:

Before the training, I did not know the PPDAC and its applicability in statistics. I just interpreted the graphs and couldn't detect elements that were wrong or missing. After the formative process, I can understand it. Thus, I realized the importance of working on these models in the classroom for student learning because, when facing graphs in their daily lives, they will have a more accurate view of the elements that are present in them. Today I can see how important it is to know statistics for our everyday life (Teacher A).

I never identified, before the training, any problem in a graph. As it was already prepared in the textbook, I never thought they could be wrong. Once I got to know how to work the PPDAC cycle, I could see how important and necessary it is to go through all the steps since the construction of the elements that make up the graph. I saw graphs on the internet, television, newspapers, and other media, and I couldn't see their mistakes. Today I can analyze a graph that I see in my daily life in a more critical way. This criticality is what we must pass on to the students, so that they can make this interpretation in a more contextualized and in-depth way (Teacher B).

Regarding the contributions the training brought to the teachers, the importance of knowing statistics due to its use in everyday life was highlighted. They began to see their teaching routine differently, whether in the critical analysis of the results of a survey, the recognition of weaknesses presents in graphs or the analysis and interpretation of data from a practical survey carried out with students. The two



teachers reported that they started to see the graphs and statistical information differently, within in the social context, noticing elements that were not visible before and analyzing the information more critically. These testimonies reveal the statistics present not only in teaching contexts, but in social contexts, bringing evidence that training contributed to the Statistical Literacy of these teachers (Gal, 2002). Lopes (2008) believes that by developing statistical literacy, teachers develop a more differentiated view of statistical information that circulates in the media.

When the teachers talked about experiencing the investigative cycle, they said that through this activity they consolidated, in practice, what they had seen in theory during training. On this topic, the teachers made the following comments:

Before the training course, I didn't know anything about statistics. I only saw tables and graphs; I didn't know what type of graph to use in a survey. I thought you could use any chart and it would work. When doing the PPDAC I saw, in practice, that not every graph would work to represent the data of a survey. The students tried the pie chart, but I, along with them, realized that it would not work (Teacher A).

I also learned how to calculate the mode, median, absolute frequency, and relative frequency. All of these were things I had a slight knowledge of, when I did business management, but I no longer remembered them. I learned that each type of research has a graph that best suits it (Teacher B).

Teacher A reveals that the training was the gateway to understanding the different types of graphs, learning the PPDAC model, and, consequently, starting to work with statistics more consistently in her routine as a teacher who teaches mathematics. Teacher B adds by saying that learning measures of central tendency are important to interpret the information that comes to us, as they create possibilities to understand the representations of the surveys that take place in society and thus understand the information that circulates in that society.

From these statements, it is possible to verify that collaborative training contributes to the development of conceptual and methodological knowledge for teaching statistics (Wild; Pfannkuch, 1999), but much more than that, for professional development (Castro-Filho *et al.*, 2022; Clarke; Hollingsworth, 2002) and literacy in statistics (Castro; Castro-Filho, 2015; Gal, 2002). Next, we will present the relationship between Ausubel's theory and the teachers' pedagogical planning.

## **5.2 The relationship between Ausubel's theory and the teachers' pedagogical planning**

The teachers' planning was carried out collaboratively and it was an important moment for reflections and meaningful learning development. Both teachers

commented that during training, they learned some statistical concepts that they believed to be essential for their pedagogical planning. On this subject, the following statements were observed:

Before the training, I was not used to reflecting on the activities I developed with the class. Today, upon learning about the model you adopted, based on planning, action, and reflection, I started to organize myself better even when teaching other subjects, and I always try to reflect alone or with my colleague, Teacher B, about my actions in class (Teacher A)

The RePaRe model applied in the training I attended helped me a lot to develop a reflection on my actions in class. I believe that reflection promotes change and, at the same time, helps me identify my mistakes and correct them so that, by practicing these actions, I am developing as a professional (Teacher B).

To Ausubel (2003), new and consolidated learning maintains a relationship of continuity with each other. The difference between them is not seen as a dichotomy, but rather a complementary relationship, therefore, we noticed that when using the RePaRe spiral, the teachers developed meaningful, not rote learning, because we observed that they learned new models of working statistics, reflecting on their a priori actions to improve their teaching practice.

The teachers were asked why some students were left out during the vote counting of the poll carried out at the school during the execution of the PPDAC. We also questioned the teachers whether the lack of detailed initial planning had repercussions for a certain difficulty in achieving significant learning for themselves during the activity and for the students when applying the practical research following the phases of the PPDAC investigative cycle in other classes of the school, to which they answered:

I didn't think that excluding some students when counting the votes would have a negative impact on the process because they told me they knew how to count the votes and that's why I asked them to advance the count by collecting the votes in the other classes, but I did not verify whether, in fact, they would know how to do the counting and categorization on their own. The lack of detailed planning hindered the development of meaningful learning for part of the class. As a teacher, after the activity, I realized that, by skipping a stage of the PPDAC with a group of students, I ended up harming them (Teacher A).

We ended up rushing a few things... At the time of data analysis, I left, and my colleague stayed in the room. When I came back, I saw that there were two chart models: a bar chart and a pie chart. However, since I already had prior knowledge that I had acquired in the training about which model was most suitable for short-answer surveys and surveys with several categories, I could understand why those graphs were chosen to represent the survey and then confirmed my hypotheses with them; they were assertive (Teacher B).

We observed that at the end of the process, Teacher A started to understand the importance of involving the whole class in the experience of each of the phases of the PPDAC, but she had difficulty knowing how to include all the students, since there was no detailed planning. Alves and Santana (2019) say that it is important for the teacher to involve all students in all phases of the PPDAC, as the active participation of each one involved promotes the development of thinking and statistical literacy components and helps in the development of a critical posture of each of the students.

The exclusion of some students affected the achievement of significant learning because the planning of the PPDAC stages was not prepared in detail. Because some students were left out of some stages, they could not acquire the knowledge to understand what would come in the next stage, and the teacher mistakenly believed that they already had this knowledge. Ausubel (2003) proposes that the teacher evaluates the student to understand what each student brings with them from previous learning, to later develop activities aimed at favoring new learning.

When proposing the activity, Teacher A did not actually verify whether the group of students she excluded from the vote count and categorization would know how to do it alone. She did not know what knowledge the group brought and did not seem to have understood how important it was for the student to experience all the phases of the PPDAC to obtain meaningful learning.

Teacher B, on the other hand, built hypotheses based on her previous knowledge. David Ausubel's theory, through cognitive relationships, defends the importance of prior knowledge for the individual to acquire new learning. In general, we observed that, in fact, the lack of detailed planning about what one wanted to achieve in each phase of the PPDAC hindered part of the class in obtaining significant learning in the process. Thus, the importance of carefully planning the activities is highlighted. It is essential to know students' prior knowledge to plan the activities to be developed in class. Below are activities developed during collaborative training that, according to the teachers, may have contributed to significant learning.

### **5.3. Activities tackled during the training that favor meaningful learning**

Teachers explained the contributions of the experience with the PPDAC for meaningful learning in relation to statistical concepts and the change in their practice in the classroom. According to them, this contribution is present in the very act of reflecting on their practice. On this subject, we observed the following comments:

Of everything I learned in the training course, the issue of reflecting on my actions to evolve as a professional was something I started to do

more frequently. Using the PPDAC in surveys was very important to open this path. I noticed my progress as a teacher. By learning the PPDAC phases, I could see that each phase brings new knowledge. That organization made me reflect on a new methodology that I did not know, and this was an evolution for me in terms of the way I teach and how I can improve my way of teaching (Teacher A).

Well, the formative course contributed much; exchanging experiences with colleagues was very good and showed other ways of working in class. One of them was awakening to the understanding of the details of a phased inquiry, as in the PPDAC. I think I changed my way of teaching forever, experiencing the PPDAC made me reflect, due to the discovery of the potential of this methodology for teaching statistical content (Teacher B).

From the moment teachers start perceiving changes in their teaching practice, they also begin reflecting on their way of teaching. To Ponte (1996), reflecting on one's practice is a path to teacher professional development. This course occurs amid the combination of formal and informal processes and happens not only through cognitive aspects, but also through teachers' affective and relational aspects (Ponte, 1998).

In this regard, collaborative formation, as Teacher A commented, is a path that contributes to the exchange of experiences and learning. It also helps teachers to reflect on their actions and review and learn new ways of teaching. Another factor perceived in the teachers' speech was the contributions of the PPDAC experience to the improvement of teaching practice. According to them, this contribution is present in the very act of reflecting on their practice, as we can see in the following comments:

Statistics and mathematics, before, were the same thing to me. But during the formative course, I learned that they are not. In statistics things vary, there is always an uncertainty, different from mathematics where it doesn't matter if you add two plus two, it will always be four. If you survey a class, the result will be different even though the questions are the same. Since each context has a different thought, there is no way to know the result. It is always uncertain (Teacher A).

We can say that Teacher A's speech agrees with Lopes (2008). By distinguishing statistics from mathematics, she reveals, in the first, the presence of uncertainty, and in the second, the work with logical rigor and precision in the results. Teacher A says that she can differentiate these two areas of knowledge and this learning was possible in the collaborative training. Understanding the differentiation of the nature of mathematics and statistics reveals expressions of the teacher's Statistical Literacy (Gal, 2002), developed from training. Regarding statistics teaching in other subjects, Teacher B comments that graphs and tables are constantly present in geography, history, and science. She says that the formation helped her realize that the PPDAC cycle can also be used in other areas of knowledge:



The collaborative training on statistics using the PPDAC cycle made me realize that we can use it not only in mathematics teaching, but also in other subjects where graphs and tables appear, as well as in content that may involve research. I also teach geography and realized that graphs and tables are very present in this subject and that I can use them to strengthen the teaching of statistics, going beyond the mathematics classes (Teacher B).

When reflecting on interdisciplinarity in the teaching and learning process of school mathematics, Tomaz and David (2013) state that mathematics gains a social status in the face of the possibility of establishing a relationship with everyday situations and when we are faced with its use in other subjects. Mathematical knowledge, therefore, is considered a way of describing and helping to understand phenomena from other areas of knowledge.

The teachers' speeches reveal meaningful learning related to content, such as measures of central tendency (mean, mode and median), construction and proper use of graphs in research, among others. There were also gains in the methodological aspect, enabling the use of an approach, such as the PPDAC investigative cycle, from the perspective of Wild and Pfannkuch (1999), which promotes students' critical and statistical thinking. The research reveals that teacher education also provided reflections and a change of attitude in the classroom, reflecting on professional development (Clarke; Hollingsworth, 2002). The protocols show reflective, but also autonomous, teachers who will possibly start to teach in a different way. The teachers had learning experiences that made it possible for them to realize that the PPDAC experience is a path to be followed for the development of thinking and statistical literacy.

The difficulties linked to the process were consolidated amid the experience of the stages, which, according to them, were related to the time factor, lack of experience with these methodological approaches, and lack of basis on the subject. However, even with these weaknesses, the activities could open new reflections in favor of modifying how they tackled statistics in the classroom, now having in the PPDAC a way to provide a more dynamic class, with the exploration of real contexts, moving away from a traditional teaching model. Next, the final considerations of this research will be presented.

## **6. Conclusion**

This work aimed to analyze the narratives of two Brazilian teachers who teach in elementary school, based on a collaborative training in statistics. Collaborative teacher education was based on the Reflection, Planning, Action, Reflection (RePARE)

spiral and explored concepts and methodologies aimed at teaching statistics. The approach used for teaching statistics included the PPDAC investigative cycle, divided into 5 phases: Problem, Planning, Data, Analysis and Conclusion.

Collaborative teacher education enabled professional development, but, above all, the learning of statistical concepts in a meaningful way. Ausubel's theory emphasizes the importance of organized and hierarchically structured cognitive structures for the retention and application of new knowledge. The collaborative experience and development of the teaching sequence with students using PPDAC helped the teachers to internalize the concepts significantly, which is evidenced by the ability to lead students to carry out each stage of PPDAC. This learning process, through the articulation between theory and practice, not only improved their pedagogical practices, but also promoted a lasting change in their educational approaches, perfectly aligning with Ausubel's theory of meaningful learning.

It was verified the importance of having as the object of study the learning experiences of the teachers resulting from the training course. Most works, as the literature shows, focus on the advantages of this process for the student and do not consider the experiences of the investigative cycle PPDAC to change the teachers' attitudes in dealing with statistics teaching. According to the teachers, the experience with the PPDAC proved to be capable of providing the learning of statistical concepts for them and the students. We noticed that research carried out in real-life contexts, such as the one developed with the investigative cycle PPDAC, serves to work on criticality and develop scientific thinking. In this regard, we can verify that activities that awaken experimentation and learning in practice are conducive ways for students and teachers to achieve meaningful learning in the classroom.

We also acknowledge that during the meetings, when teachers learned the PPDAC, they recognized the role of statistics and its relevance as a science to promote skills development. These skills, which were perceived in the teachers' speeches, showed evidence of meaningful learning in relation to the contents of statistics and on the development of skills by the teachers. Thus, when experiencing the phases of the PPDAC in the formative process, the teachers began to prove that they were developing skills characteristic of statistical thinking through contact with the data during the phases of the investigation, and of literacy, when they revealed understanding, after the formative activities, the weaknesses present in graphs that circulate in books, newspapers, and television media.

Finally, we conclude that the teachers participating in this research showed signs of having acquired new knowledge. In addition to learning statistical concepts, they also developed methodological knowledge for teaching statistics and critical thinking and reasoning skills when analyzing the data obtained from a survey. The teachers began questioning the integrity of the data obtained in real-life situations, approaching everything more critically. After the formative activity, the teachers expressed interest in conducting their own surveys instead of relying on pre-existing data from third-party sources, which had been their usual practice. Thus, the learning acquired in this course provided a foundation for transforming the teachers' approach to working with statistics in the classroom as it provided a reflective process on practice, translating into activities of co-production of knowledge, training, reflection on the practice and professional development.

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