ADDRESSING WATER SCARCITY THROUGH STATISTICAL INQUIRY IN TEACHER EDUCATION

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ABSTRACT

This article presents the design and implementation of a study and research path for teacher education (SRP-TE) based on the Anthropological Theory of the Didactic. The goal is to analyze this teacher education proposal for inclusive statistics education aiming to overcome constraints derived from the phenomenon of the transparency of data treatment. The proposal starts with a newspaper report about the loss of water resources in Brazil and questions the data supporting it. The study focuses on one of the participating teachers from a disadvantaged region in the Northeast, where she worked in a rural school with few resources and poor infrastructure. The course helped her implement an inquiry activity with her sixth-grade students and mobilize digital resources for data visualization and graph representations. This case study contributed to analyzing how the SRP-TE promoted teachers' professional development and provided elements for teaching inclusive statistics.

Keywords: *Statistics education research; Study and research path for teacher education; Secondary school; Inclusive statistics; Digital resources*

1. INTRODUCTION

Brazil, as a nation characterized by significant social and geographic inequalities, has implemented educational strategies to address cultural, social, and economic inequalities. The goal of inclusive education is to ensure that everyone can receive an education. It assumes equal opportunities for all and the value of individual differences, considering, among other things, the ethnic, social, cultural, intellectual, physical, sensory, and gender diversity of people (Kollosche et al., 2019; OECD, 2023). To guarantee access, participation, development, and learning for everyone implies the reform of the education culture, practices, and policies currently in place. Despite the current legislation, many challenges remain, like the restrictions due to poor structural conditions of public schools, the lack of specialized professionals to monitor students, and students' learning diversities (Alquati Bisol et al., 2015; Cury, 2005).

We adopt the perspective of inclusive statistics education that focuses on ensuring that all students have access to statistics education, recognizing the diversity of students in the quest to adapt the teaching of statistics so that it is accessible, relevant, and meaningful for all (Kollosche et al., 2019; Witmer, 2021). We assume that statistics might play an important role to confront inequalities in the classroom and develop critical thinking and decision-making skills when working on an inquiry-based

approach using open questions in real contexts. Over recent decades, statistics have evolved in line with the development of technological resources for data processing, giving rise to what is known today as "data science" (Loy et al., 2019). Statistics education has responded similarly adapted in line with the changes. A review of the literature revealed the emphasizes put on the importance of taking a broad view of this field, including aspects of searching and collecting data in real-world contexts; selecting, organizing, tabulating, and visualizing data; using specific software, simulation, and reporting to answer open-ended questions; and study the variability of specific phenomena (Burrill & Ben-Zvi, 2019; Shaughnessy, 2007). This field is consolidating in terms of "statistical reasoning" (Ben-Zvi & Garfield, 2004), "statistical literacy" (Watson, 2016), and "statistical thinking" (Wild & Pfannkuch, 1999).

The problem of how to address inclusive statistics in teacher education has been developed as an important line of research (Casey & Ross, 2022; Dogucu et al., 2023; Kollosche et al., 2019; Ni Bhroin & King, 2020; Witmer, 2021). Although data gathering and processing are becoming increasingly important in society (Ben-Zvi, 2020), they still do not have the same status in school mathematics. As stated by Batanero et al. (2011) and Burrill and Ben-Zvi (2019), statistical activities are often reduced to numerical calculations of statistical measures (e.g., frequencies, measures of central tendency, deviations) and the creation or interpretation of standardized graphical representations (e.g., pie or bar charts, histograms, and scatter plots). This was made clear some decades ago by Short and Pigeon (1998) when they noticed that, although statistics educators seem to agree that data gathering and analysis steps are valuable, "the planning and piloting phases of data collection are often neglected" (p. 1). Even though recent national curricula include aspects such as data collection, organization, recording, planning, and executing a sample survey (see Brasil Ministério da Educação, 2018), rarely do textbooks include related activities (Prestes, 2021; Verbisck & Bittar, 2021). Fewer still are textbooks that promote working with big and real data sets that call for initial steps of selecting, cleaning, and organizing data to be analyzed.

Ben-Zvi and Garfield (2004) emphasized that "students equate statistics with mathematics and expect the focus to be on numbers, computations, formulas, and one right answer" (p. 4). Similarly, Chevallard and Wozniak (2007) described and analyzed this situation in terms of the prevalence of "the reduction of statistical work to arithmetical work." This reduction is part of a broader didactic phenomenon we call the *transparency of data treatment*. It refers to the school's difficulties in providing an official role and status to all the work with data that is not seen as arithmetical work, for example, data gathering, processing, management. This phenomenon sets up important constraints for the teaching and learning of statistics, in particular, in secondary school (Verbisck et al., 2024).

The research reported in this article focuses on designing, implementing, and analyzing a teacher education proposal for inclusive statistics education designed to overcome constraints derived from the phenomenon of the transparency of data treatment. On the one hand, we aim to promote an online teacher education proposal based on the so-called *study and research paths for teacher education* (SRP-TE), as proposed by the Anthropological Theory of the Didactic. It is proposed, the SRP-TE progresses with teachers in the development of inclusive statistics education to address relevant societal questions and use digital resources. In this case, the context of the classroom inquiry undertaken was the environmental problem of water scarcity in some regions of Brazil. On the other hand, we aim to analyze the conditions facilitating and the constraints hindering the construction and transference of an official status to data treatment in teacher education and in secondary school. The research questions addressed in this paper are:

RQ1: In what sense can a teacher education proposal, based on an SRP-TE, help teachers promote inclusive statistics? What kind of activities and through what interaction with digital tools facilitate teachers' reflections on inclusive statistics?

RQ2: What conditions implemented in an SRP-TE can help teachers address and detach themselves from the phenomenon of the "transparency of data treatment" in a context of online in-service teacher education? What constraints limit it?

We address these research questions through a case study based on a teacher education proposal for statistics we designed and implemented in an online course in Brazil. The course sought to pursue three main goals. First, it involved in-service teachers in enquiring into a problem about water scarcity using statistical knowledge. Second, it provided teachers with design tools to implement a similar activity to

be transferred to secondary school. Third, it aimed to help teachers approach teaching resources more productively, particularly in terms of their understanding of statistics. The study focuses on one of the cooperating participants, who worked in a rural school with few resources and poor infrastructure in an impoverished district of the Northeast. The training helped her to implement an inquiry project with her sixth-grade pupils, as well as use digital resources for data visualization and graph representation. This case study contributed to understanding how the SRP-TE enhanced teacher professional development and provided aspects for teaching inclusive statistics using digital resources.

2. THEORETICAL FRAMEWORK

2.1. THE ANTHROPOLOGICAL THEORY OF THE DIDACTIC AND THE CHANGE OF PARADIGMS

The Anthropological Theory of the Didactic (ATD) is an educational theory developed by Chevallard, a French mathematician and researcher. In the 1980s, the theory arose as an attempt to comprehend the process of knowledge construction and acquisition in the field of mathematics education. The ATD theorizes how knowledge is produced, disseminated, communicated, and received in social institutions, and how these processes affect the interactions between teachers, students, and the subject matter being taught. It started in the field of mathematics education but has been used in a wide range of different subjects and educational settings. The need to develop further didactic tools and devices for teacher education, as well as to study their functionality, impact, and diffusion, is supported by recent research in the ATD in terms of a change of pedagogical paradigm from the *paradigm of visiting works* towards a new *paradigm of questioning the world* (Chevallard, 2015).

According to Chevallard (2015), school education mainly takes part in what he referred to as the paradigm of visiting works in contemporary societies. Students' responsibility in this paradigm is to study content prescribed by rules and according to ready-made categories of different sizes: topics, areas, domains, and disciplines. The students must study and value these works without necessarily challenging their validity or worth. Hence, in this paradigm, themes and subjects are like monuments: students cannot change them; they do not need to understand why they exist; all they must do is study them. The instructor, who is referred to as "the one who knows," is the one who presents the works to study and proposes tasks for the students to get familiar with them and acquire a certain mastery of their use in different types of tasks. In contrast to this first paradigm, Chevallard (2015) described the *paradigm of questioning the world* in which content is organized by *questions,* and teaching and learning result from inquiry processes aimed at answering these questions. In other words, students are the inquirers of the generating questions (Q) proposed by the curriculum. There may be times when exploration and research are required in the search for answers to a question, but with a specific *raison d'être*: elaborating and justifying an answer to Q.

The new paradigm creates a strong change in the *didactic contract* that prevails in the first paradigm, that is, the kind of responsibilities assumed by teachers and students regarding the knowledge to be studied (Brousseau et al., 2020). In the new paradigm, teachers do not introduce the knowledge tools needed to answer the questions addressed. They act much more as leaders of the research process developed by the students. The change affects not only the pedagogical level, "How to teach?", but also the epistemological level, "What to teach?" Knowledge is learned during the inquiry of relevant questions using dynamic, provisional, and collective tools.

The change of paradigm introduced by the ATD promotes different changes. First, it gives the school the mission to address important social problems that affect all students, similarly. It then gives priority to the study of the questions and problems raised and not to the tools needed to answer them. In this context, data analysis appears as an essential tool for inquiry even if it is not always valued as official statistical knowledge or does not have any official status in school. In this context, inclusion means taking students' real problems seriously and showing them that a school is a place where these problems can be studied and addressed, to bring new knowledge about what matters to society (Casey & Ross, 2022; Kollosche et al., 2019; OECD, 2023; Skovsmose, 2019; Witmer, 2021). In this same line, steps towards the paradigm of questioning the world might help to establish better conditions for inclusion and inclusive statistics: important questions can be addressed in the school with all students are concerned, who can be given the chance to address these questions in class. Questions addressed

should not be fake problems to motivate the use of statistical tools (decided beforehand), but real problems a statistical inquiry approach can address better.

2.2. STUDY AND RESEARCH PATHS FOR TEACHER EDUCATION

To investigate the *ecology* of the transition of paradigms (i.e., the conditions needed to encourage the transition between the two pedagogical paradigms and the constraints that hinder it), Chevallard (2015) put forward a teaching proposal called *study and research path* (SRP). It can be described through the so-called *Herbartian schema*: $S\ (X;\ Y;\ Q_0) \hookrightarrow A^{\heartsuit}$, where a group of students X, helped by a group of teachers Y, form a didactic system S to address an initial question Q_0 and provide a final answer $A^{\heartsuit}$. In the process from Q_0 to the collective elaboration of $A^{\heartsuit}$, the *didactic system* $S\ (X;\ Y;\ Q_0)$ displays Q_0 into derived questions Q_i, searches already available "labeled" answers $A_j^{\diamondsuit}$, elaborates and adapts them to Q_i, finds new questions during the process which, in turn, call for new answers, and so on.

Bosch (2019) pointed out the importance of the *questions and answers (Q-A) dialectic* to ensure the dynamics of SRPs. The *Q-A* dialectic provides visible proof of the progress of the inquiry and contributes to the overall process management. To elaborate $A^{\heartsuit}$, the didactic system creates a didactic *milieu M*: $[S\ (X;\ Y;\ Q) \rightharpoonup M] \hookrightarrow A^{\heartsuit}$. This *milieu* is composed of derived questions Q_i, "ready-made" answers $A^{\diamondsuit}_j$ that seem helpful to answer Q_i, any kind of works W_k (knowledge or material), and the sets of data D_m gathered during the inquiry. The extended *Herbartian schema* is symbolized as:

$$[S\ (X;\ Y;\ Q) \rightharpoonup \{Q_1, Q_2, \ldots, Q_i, A^{\diamondsuit}_1, A^{\diamondsuit}_2, \ldots, A^{\diamondsuit}_j, W_1, W_2, \ldots, W_k, D_1, D_2, \ldots, D_m\}] \hookrightarrow A^{\heartsuit}$$

The *media-milieu* (*Me-Mi*) *dialectic* becomes crucial during the whole SRP. To analyze this dialectic, scrutiny is placed on where external information, data, and answers come from, and how access to data and information are managed (*media*). Explored also is how data and information are validated and transformed, and with what materials the final or intermediate answers are developed (*milieu*). Finally, an SRP is a collective inquiry process during which small groups X_i are formed and individual work is also carried out. X_i and Y_j should organize themselves to work together. To analyze the responsibilities and roles assumed by X_i and Y_j during the development of an SRP, the notion of *didactic contract* explained above, is used.

Ruiz-Olarría (2015) extended the proposal of the SRP to the *study and research paths for teacher education* (SRPs-TE) to provide teachers with relevant (theoretical and practical) tools to undertake activities close to the paradigm of questioning the world. For this purpose, an SRP-TE consists of five modules (Figure 1). As in all SRP, the starting point is a generating question related to the teaching profession (Module 0). Partial answers to generating question will appear throughout the SRP-TE (and it is expected that afterwards, it will also continue to appear), making it a transversal module of the educational process. Then, teacher-students progress through an SRP to experience the inquiry process (Module 1) and analyze the joint experience from a didactic perspective (Module 2). The proposal is adapted to suit school conditions and implemented (Module 3), to be finally analyzed (Module 4) to provide provisional answers to the initial teaching question (e.g., What is possible and how? What seems difficult and why? What are the consequences?).

The first online SRPs-TE were designed and implemented in Mexico and the findings in that investigation highlighted the practicality of the methodological adaptation, especially in the identification of institutional constraints that are typically hidden from instructors in their daily work (Barquero et al., 2018). In this paper, we report on the analysis of the teachers' behavior during the different modules of an SRP-TE, paying special attention to the difficulties found in using the ATD tools introduced to describe, design, and implement inquiry processes related to data treatment. These difficulties are likely to be constraints coming from the prevailing paradigm of visiting works and the related phenomenon of transparency of data treatment in secondary school mathematics. The study also investigates how the teacher education proposal made it possible to promote inclusive statistics using digital resources in an inquiry process, based on the study of an environmental question close to the students' social context. The design and implementation of the online SRP-TE applied to the Brazilian teachers' education context; adaptations were made based on previous studies that will be detailed in the following section.

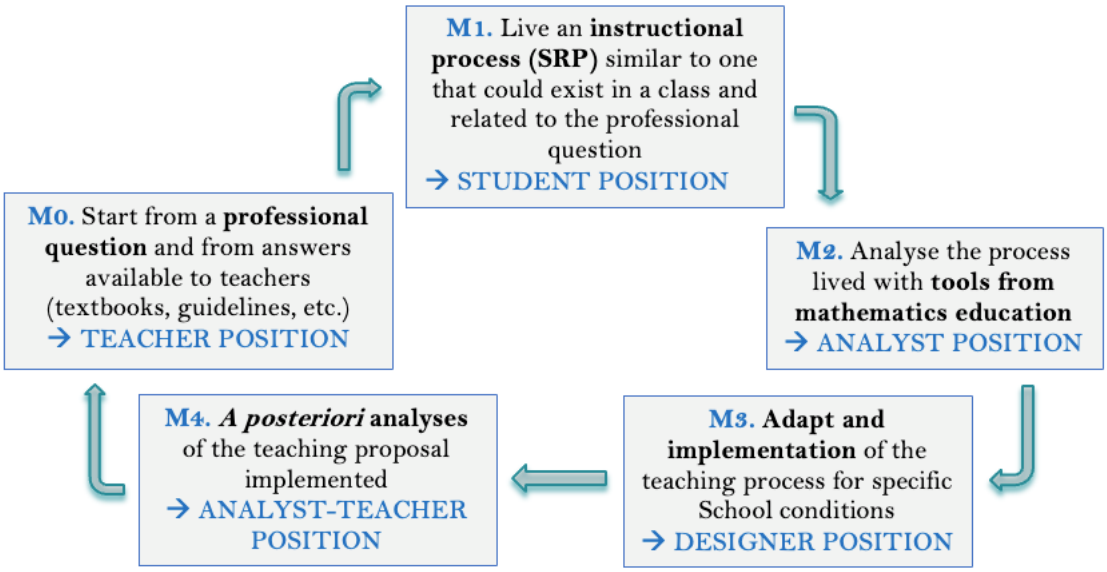

Figure 1. The general structure of an SRP-TE

The methodology of our research is qualitative and exploratory. The design, implementation, and analysis of the SRP-TE follows the didactic engineering research principles as described in Barquero and Bosch (2015). They consist of four major steps. The first step is the *preliminary analysis* where the didactic phenomena to be addressed are identified (M0). In this case, as mentioned before, it corresponds to the transparency of knowledge related to data treatment at the secondary school level. The second step is the *a priori analysis* and entails designing an inquiry activity related to the phenomenon under consideration—in this case, an SRP-TE course—to make the phenomenon visible and test the potentialities of the proposed instructional activity (M2). The third step is its implementation, observation, and *in vivo analysis* of the activities planned in each of the modules (M3). Finally, the fourth step is the *a posteriori analysis* based on the analysis of the teachers' educational activity, as well as the development of knowledge about the initially identified didactic phenomenon (M4). The data gathered include the educators' and teachers' productions during all the SRP-TE, the transcripts of their exchanges in the course sessions, and interviews with the participants who implemented an adapted SRP in their classes.

3. THE DESIGN OF AN ONLINE SRP-TE FOR IN-SERVICE TEACHERS IN BRAZIL

3.1. PREVIOUS STUDIES AND RESULTS

In a previous investigation, when looking at Brazilian textbooks, we found a school exercise about a bar graph of "Distribution of Brazil's water resources, surface, and population." Although the context of the school exercise seemed highly relevant to be discussed in the classroom, it only presented questions about the kind of graph and the interpretation of some of its elements. Building upon this exercise, we developed a comprehensive set of a generating question and derived questions that could arise during an inquiry-based approach (Verbisck et al., 2022a). This *a priori* analysis serves as a potential SRP to be implemented in mathematics teacher education.

Subsequently, we conducted an online pilot study with pre-service teachers from the Federal University of Sergipe (Brazil). Our goal was to turn the school exercise about "Distribution of Brazil's water resources, surface, and population" into an inquiry activity, moving it away from the paradigm of visiting works toward the paradigm of questioning the world (Verbisck et al., 2022b). The characterization of the main phenomenon considered here, the *transparency of data treatment*, resulted from this study. This experience inspired us to design and implement the online SRP-TE presented in this article. The discussion and analysis of the SRP-TE are explained from Section 4 onwards. Before

that, we present a more detailed description of the design of this proposal and the digital infrastructure created for the development of the course.

3.2. THE ONLINE SRP-TE STRUCTURE AND ITS MAIN DIGITAL INFRASTRUCTURE

The SRP-TE was implemented as an online modality course from September to December 2022 for in-service secondary school teachers in Brazil (voluntary participation). It was planned and implemented in partnership with researchers from the Pontifical Catholic University of São Paulo , the Federal University of Mato Grosso do Sul, the Federal University of Bahia , and the University of Barcelona . The course took place in 14 sessions on Saturday mornings, each session lasting three hours, with a short break. Participants were required to attend the course sessions and complete some after-class work, implement a teaching proposal some weeks in November/December, and to write a final report about the different phases of the SRP-TE. We used the *Microsoft Teams* platform as part of the infrastructure for online synchronous sessions, some in small groups and others with the whole class. *Microsoft Teams* was also used as a document repository. All online *Microsoft Teams* sessions were recorded.

In M0, the generating question $Q_{0\text{-}TE}$ was *How should we teach statistics and probability in secondary school?* In this module, the educators presented $Q_{0\text{-}TE}$ as a cross-curricular issue in all the other modules. Our didactic system was composed of three groups working in parallel and carrying out different SRPs under the guidance of three educators. Reported in this article are the outcomes for one group of teachers, those addressing the question related to water scarcity. It was formulated as follows: *"Brazil has lost 15% of its water resources in 30 years, a loss of almost twice the water surface area of the entire Northeast region." How to analyze the veracity of this news?*

The choice to divide the participants into three groups to carry out different SRPs in M1 was due to several factors. First, the initial group of registered participants comprised of over 100 people, and we considered that only groups of up to 30 participants were manageable. Second, we thought that proposing three different SRPs would illustrate different contexts for inquiry activities and broaden the type of statistical and probability tools expected to be implemented during the inquiries. Hence, the moments of general discussions become critical to share the progress of the SRPs, the common and specific difficulties encountered, and the ways used to overcome or interpret them. The first author of this article coordinated the group included in the analysis.

In *Microsoft Teams,* we created four permanent rooms: a general room for discussions and sharing with the three groups together, and a room for each group to work on the SRP-TE modules based on the different SRPs. The sessions had a general structure: all sessions but two (8^{th} and 13^{th}) were divided into two parts, one with all the participants to introduce the work to do (including discussing issues related to the methodology of the SRP), provide new tools and explanations, and discuss the results obtained; and another one dedicated to group work. Between one session and the next, the team of researchers analyzed the development of the online SRP-TE, adapted the initial schedule when necessary, and made decisions about the next steps to take in the course. Many discussions corresponded to the choice of digital resources that would enable the interaction of the work groups and the storage of their productions. The main digital tools employed during the SRP-TE and their main functions are listed in Table 1. More details of the sessions' structure are presented in Verbisck et al. (2024).

Table 1. Digital resources and their functions in the online SRP-TE

Digital resources	Mean functions of use during the course
Microsoft Teams	- Synchronous meetings, group work and collective discussions. - Document repository for suggestions of materials and readings for participants, as well as storage of teamwork. - Used to store the recordings of the sessions.
WhatsApp	- Keep in touch with participants from one session to the next (news, reports, etc.). - Follow the progress of the implementations of research activities during M4.
Padlet	- Online collaborative platform used for the collective production of questions-answer maps in M1.
Websites and digital publications	Webpages, e-books, online journals, and articles used to: - Search for "ready-made" answers $A^{\Diamond}_j$, - Search and download data D_m, - Search for objects O_k of different kinds.
Microsoft PowerPoint	Software used by educators to present the course structure, timetable, progress of sessions, and interventions on specific topics. For example: at each session, in the general *Microsoft Teams* room, PowerPoint was used to carry out recaps of the work developed so far in the three different groups.
Google Drive	Cloud-based file storage and synchronization service used for teamwork productions: each team worked collectively in the same *Google Drive* document, which facilitated the storage and recording of all group productions.
Online Databases	Digital repositories of information used to search and download data about the subject being investigated, for example, water resources in Brazil.
Microsoft Excel	Software used to work with data: the data found in the database were downloaded in ".xls" format and for the organization, analysis and visualization of the data, the group members used the functions offered by the software to construct absolute and relative frequency tables, graphs of different types, comparison parameters, etc.

All these digital resources, and especially the connections among them, were crucial for the construction and evolution of the *media-milieu dialectic* in our online SRP-TE. In the result and discussion sections, we will see how some of these digital resources were used during the modules, especially, by one of the teachers participating in the course (Paola's case) in adapting the SRP experienced in module M1 to her sixth-grade classroom.

4. RESULTS

4.1. MODULES 0-2: EQUIPPING TEACHERS WITH DIDACTIC TOOLS AND PROMOTING INCLUSIVE STATISTICS

In M0, the $Q_{0\text{-}M0}$ was, "*How should we teach statistics and probability in secondary school?"* In this module, the educators presented $Q_{0\text{-}M0}$ as a cross-curricular issue in all the other modules and gathered more specific questions raised by the participants. While grouping and commenting on these questions, the differences between the paradigm of visiting works (to which most of the questions refer) and the paradigm of questioning the world were explained. In M1, the first author of this article (represented by *y*) was the coordinator of Group 1. This group was comprised of six secondary in-service teachers. An inquiry activity was proposed starting with a Brazilian newspaper report related to water resources, about which the question of the veracity of the data presented was raised ($Q_{0\text{-}SRP1}$). We saw how considering this activity within the paradigm of questioning the world leads to its extension by incorporating dimensions of the statistical work that tend to be absent in secondary education, such as the search, collection, cleaning, and representation of data, as well as the critical reception of information based on data. We also saw how the generating question $Q_{0\text{-}SRP1}$ encouraged critical thinking and research skills to evaluate the credibility of news sources and claims related to environmental issues.

Once the generating question was presented by *y*, the participants had difficulties in raising questions about the theme exposed in the report. To address this issue, *y* assumed the role of motivator of the group and stimulated the participants to first carry out a careful reading of the report and then

discuss possible questions that would derive from $Q_{0\text{-SRP1}}$ and the reading performed. Putting the participating teachers in the position of "inquirers" of a news report required a change in the didactic contract with which they were not familiar. The coordinator *y* tried not to interfere in this first moment of raising questions and observed the dialogues that emerged. She noticed that some participants asked, "But, what should we ask?" as if *y* expected certain specific questions. This type of behavior is strongly linked to the dominant paradigm of visiting works, in which teachers usually know the answer to the assignments proposed in advance, and consequently, students believe that the teacher expects a certain answer to a requested task.

After reading the entire newspaper report, we realized that the participants took $Q_{0\text{-SRP1}}$ seriously and began to elaborate on questions derived from the newspaper report. The questions were grouped by themes (Table 2) and related to aspects of inclusive statistics (Kollosche et al., 2019; OECD, 2023; Skovsmose, 2019; Witmer, 2021), showing the focus of the questions on water resources, conservation, and their impact on various aspects of society and the environment.

Table 2. Questions grouped and their relationship with inclusive statistics

Questions raised	Relationship with Inclusive Statistics
Q_1: *What data are presented in the news?* $Q_{1.1}$: *Are there official databases that provide these data? Can we access them?*	• Promoting awareness of available data sources, how to access and interpret this information for informed decision-making
$Q_{1.2}$: *What information can we get from the databases?* $Q_{1.2.1}$: *How are the data from the databases produced?*	• Promoting the exploration of the methodologies behind data collection, stimulating the study of the techniques used to gather accurate and reliable information.
$Q_{1.2.2}$: *What data can we use for the analysis?*	• Selecting relevant data for analysis, developing a deeper understanding of the factors contributing to water resource loss.
Q_2: *How can we corroborate the diagnoses mentioned in the news report?* $Q_{2.2}$: *What statistical knowledge could help get results and see if they match the news information?*	• Encouraging cross-referencing data and seeking expert opinions to verify claims. Incorporating statistical analysis skills to interpret and draw conclusions from data and validate or question the claims made in the news.
$Q_{2.1}$: *What is the water situation of each Brazilian region?*	• Promoting learnings about the specific water situations faced by different regions in Brazil, emphasizing the importance of understanding the local context.

Overall, these questions reflect the application of critical thinking, data analysis, understanding of local contexts, and awareness of interdependencies within the environment. Due to the limited time, the group decided to investigate these questions, but they also raised eight more questions that are not explained in this article due to space constraints. In the corresponding answers to questions $Q_{1.1}$, $Q_{1.2}$, $Q_{1.2.1}$, and $Q_{1.2.2}$, the group downloaded the data from the *MapBiomas* database (the one presented in the newspaper report) and worked with *Excel*. To elaborate $A^{\blacktriangledown}$, they organized the data from 1985 to 2020 into a table and constructed bar graphs and line graphs of the five Brazilian regions to make comparisons among water losses. They were unsure about the main tools to create tables and graphs. They also had difficulties in choosing between a bar graph or a line graph to represent these data and raised some questions concerning these difficulties.

Four sessions were set aside for the development of this SRP. The research team was aware that it would not be enough time to investigate in depth all the issues raised. The aim of M1, however, was for in-service teachers to realize, albeit superficially, how an inquiry activity can work. We also intended to equip teachers with didactic tools, especially with the introduction of an inquiry activity within the paradigm of questioning the world, so that they could collectively design an inquiry activity to be implemented in the classroom. The educators also helped teachers to find some answers to the statistical questions raised, by providing them with resources or directing them to information.

In M2, the collective analysis of the SRP was conducted using didactic tools that the educators introduced according to their pertinence. Three main discussions were promoted in this module. First, a description of the experienced SRP using the *Herbartian schema* and the two dialectics: the

participants identified the derived questions raised (Q_i), the works (W_k) and data (D_m) used for the elaboration of some answers, and the questions that remained open. They did not incorporate any already available ready-made answer ($A_j^{\diamondsuit}$) because of the time shortage, but highlighted some of the themes they believed were important to study and incorporate in their *milieu*, such as:

- Water resources in Brazil: several types of analysis carried out by other agencies
- Construction of tables and main elements
- Types of statistical graphs, main elements, and relations to the data properties
- Loss comparisons in percentages, calculation of annual changes (absolute and in percentages)
- Functioning of hydroelectric plants, rainfall rates, and deforestation in Brazil

The educators also promoted a discussion about the difficulties met in trying to develop the inquiry activity within the new paradigm of questioning the world, especially to notice the elements of the traditional didactic contract that were strongly modified. Finally, the participants were asked to identify the statistical knowledge used for the elaboration of $A^{\heartsuit}$. The group pointed out the construction of tables with data, the construction of graphs, comparisons of loss in percentages, and the calculation of the annual variation (absolute value and percentages). It is worth noting that much of the previous work—database search and access and its organization—was not considered as part of the statistical knowledge.

4.2. MODULES 3–4 AND PAOLA'S CASE: TRANSFERRING THE SRP TO A SECONDARY CLASSROOM

M3 was devoted to the collective design of a proposal for an inquiry activity based on the SRP developed in M1. To do so, teachers were given the following instructions:

> *Work in your group to design an activity project adapted to the secondary school level. Think about the following questions:*
> - *What is the generating question?*
> - *How is the question posed, what is proposed, and what tools are available?*
> - *How is the study planned to be administered in class (approximate timetable)?*
> - *How is the activity expected to be completed?*
> - *What curriculum content (in mathematics and other subjects) can be addressed by the proposed activity?*

Paola volunteered to implement an SRP with sixth-grade students (11–12 years old). After all the discussions held in M1 and the collective analysis in M2, she became interested in working on the topic of rainfall levels in the region where she lived, Agreste, Northeast of Brazil. In relation to other regions, it suffers the most from lack of rainfall and, consequently, extreme drought for much of the year. This makes the residents of this region look for ways to store water from rain and rivers. Paola believed that it would be interesting and important to design and propose an inquiry connected to a social issue and the students' daily life. In addition, as she worked in a rural school with few resources and poor infrastructure, she sought to address these difficulties and promote inclusive education.

Paola took the initiative to propose a generating question based on a news report from a local newspaper entitled "Emergency decree in Pernambuco due to drought in 61 cities of Agreste." The news report mentioned the list of cities affected by drought and, among them, the city where the school is located (Pesqueira). Group 1 and *y* designed an SRP that took this news as a starting point: *What is a drought emergency? When is it declared?* With this in mind, we designed an SRP proposal based on the general guidelines: we raised questions that we believed would arise in the classroom, we planned the class time and the digital resources and other materials to be used in each lesson, we anticipated how Paola would lead and organize the students in nine lessons, we prepared how the inquiry activity would be closed, and decided on the curricular contents to be used.

Paola implemented this inquiry activity over three weeks, during a total of nine 50-minute lessons. In her class of 26 students, three of them had reading disabilities. These three students did not have any medical report attesting to a disability and had not been referred to specialists for any type of care. Table 3 presents how the SRP was implemented in Paola's lessons, highlighting the main activities developed by the students and how they were organized and guided by the teacher, also detailing the media used, and the curricular contents involved.

Table 3. Paola's SRP in sixth grade

Lessons	Description	Media	Curricular content
1st: 17/11/22	In the regular classroom, Paola organized the students in pairs or groups of three. She carried out a collective reading of the newspaper. She proposed Q_0, and then the teams began to elaborate *Qi*: *Q_0: What is a drought emergency? When is it declared?* *Q_1: What are the water resources in our region? What is the name of the river that runs near the school (Pesqueira town)?* *Q_2: Is the water from rivers and wells drinkable?* *Q_3: Where is the town of Salgadinho?* *Q_4: What are the rainfall levels in our region?*	The report was *printed* for each student. Paola used the *blackboard* to write down the questions raised. The students prepared a report and wrote the list of questions about the text in their notebook.	Identifying variables and their frequencies, and the elements (title, axes, legends, sources, and dates) of different types of graphs.
2nd: 18/11/22	In the technology room, the teams performed some searches using different Internet media to find answers $A^{\Diamond}_j$ to Q_i. The students incorporated some $A^{\Diamond}_j$ into their *milieu* and wrote down the "source" in which they found the answer (as requested by Paola). In some moments, the students also used Paola as a media source and indicated in the notebook: "Source: teacher Paola".	*Computers* with *Internet access* for the sources in various *Websites*. The students wrote the answers found in their *notebook*. Using *PowerPoint*, Paola presented a map to identify the water resources of their region and the cities surrounding them that were in the list of the newspaper report.	Interpreting and solving situations involving research data on environmental contexts, sustainability, traffic, responsible consumption, presented by the media in tables and different types of graphs and writing texts with the aim of synthesizing conclusions.
3rd–5th: 21/11/22 and 22/11/22	Q_4 prompted Paola to hand out a table with data on average monthly rainfall for the town where they live and for eight surrounding towns (Fig. 2, Part A). These data were collected by Paola from a database she found online. Hence, to seek answers to Q_4, the students began to construct bar graphs of the nine cities they had selected (Figure 2, Parts B and C). First, Paola made two collective bar graphs representations, then, in the other lessons, she guided the students to create their own.	*PowerPoint* to present an example of a bar chart representation made in *Excel*. Paola used the *blackboard* to construct the bar graphs. The students made the graphs in their *notebooks* using *checkered sheets*, *rulers*, and *pens of different colors*.	Planning and collecting research data on social practices chosen by the students and using electronic spreadsheets to record, represent and interpret the information in tables, various types of graphs and text.
6th–7th: 29/11/22 and 1/12/22	Paola reviewed everything the students had done so far. She summarized the inquiry in four parts: "research and questions about the newspaper story", "presentation of data", "working with data and representations" and "presentation and analysis". As they were still in the third part, with the monthly rainfall levels table, the students continued with the bar graphs representations guided by Paola.	Paola used *PowerPoint* to present the summary of Lessons 1–5. The students made bar graphs representations on checkered sheets, using rulers and pens of different colors.	Interpreting and developing simple flowcharts, identifying the relationships between the objects represented (e.g., position of cities considering the roads that connect them, hierarchy of employees in a company, etc.)

Table 3 (cont.). Paola's SRP in sixth grade

Lessons	Description	Media	Curricular content
8th–9th: 6/12/22	In the final lessons, Paola proposed a final analysis of the bar graphs. She displayed all the graphs on the blackboard and led a collective discussion on the following guiding questions (Figure 2, Part D): What comparisons can we make between the graphs constructed? Which months of the year show less rainfall in the municipalities observed? What conclusions can we reach about the different levels of rainfall?	Blackboard for displaying the graphs. The students wrote the answer for these final questions in their notebook.	Solving problems involving information presented in tables and/or graphs (Brasil Ministério da Educação, 2018).

Figure 2. Illustration of Paola's class work using statistical graphs (lessons 3-9)

As seen during the SRP developed by the trainee teachers (M2) and in the case of Paola's implementation, the questions studied by her sixth-grade students incorporated aspects related to environmental issues. Q_1 was about the importance of understanding local water resources, and especially, identifying the river near Pesqueira town's school as an example of a valuable natural resource. Q_2 was a quest to understand water safety from various sources and the importance of knowing whether river and well water are fit to drink, and it relates to the broader goals of environmental awareness and public health. Q_3 was raised by the students only because they were interested in the singular name of the city. Answering the question, however, incorporated discussion about the geography and environmental issues to discuss the importance of locating the city of Salgadinho in its broader environment. It also showed how understanding the location of the city could contribute to a holistic understanding of its ecological challenges and potential strategies for sustainable development. Q_4 promoted analysis and discussion about monitoring and understanding regional precipitation patterns as a crucial aspect of environmental awareness and the subsequent implications for water availability.

During the implementation (M3), Paola received support mainly through conversations in a *WhatsApp* group with the other teachers. She commented she felt safer when implementing these lessons with the support of her group and always kept the other members informed (even if at a distance and virtually) about the progress of the activity. In addition to the *WhatsApp* group, the implementations were also shared and monitored during the Saturday sessions, in which discussions were held in the *Microsoft Teams* general room about how the participants' implementations went during the week (e.g., difficulties or unforeseen events and what created them; and adjustments and readjustments of the planning of activities, etc.). In summary, Paola's implementation of the SRP created an inclusive statistics education scenario by connecting the inquiry to students' realities, adapting methodologies to suit the school's context, fostering collaboration, and employing diverse teaching strategies. However, some unforeseen events arose throughout the implementation, such as class cancellations or unplanned school events, which led to adaptations to the nine lessons. While certain limitations were acknowledged, the project demonstrated a commitment to inclusivity by engaging students in a meaningful and interdisciplinary learning experience.

In M4, Participants and educators jointly analyzed the SRPs implemented And took the opportunity to share comments about the experience. In the case of Paola, we identified how the teacher succeeded in managing the different dialectics of the inquiry process. For the *Q-A dialectic*, she encouraged her students to elaborate on other questions and search for answers in different media. For the *Media-Milieu dialectic*, she used different sources, such as the Internet, maps of the region, or a database she pre-selected. All these elements contributed to incorporating new objects into the students' *milieu*. The students were asked to include the source of information ("the Internet", "the teacher", etc.) in the partial answers proposed in their logbooks. It was observed that Paola tried to change the predominant *didactic contract* by working on a different classroom dynamic, including organizing students in pairs and trios, proposing to go to the technology room, and preparing collective graphs. She also tried to adopt a new role and took on the responsibility of guiding the inquiry process without being the privileged media or providing answers to the students' questions.

Finally, we would like to highlight an episode showing that the SRP-TE was not fully able to remove some constraints related to the *transparency of data treatment*. The episode refers to the comment by another participant x_3 regarding Paola's implementation:

> x_3: Paola, it seems interesting to me what you did, but *statistics* is different because it is data analysis, the calculation of measures of central tendency, even more so. But you [Paola] didn't have the opportunity to do this part which, in my opinion, is the most important.

Although Paola' students created graphs from information about the rainfall in different months and cities—using them to analyze the data (creating, interpreting, comparing graphs, and summarizing conclusions)—x_3 expressed the transparency of this statistical knowledge yet again. She continued to identify it with the calculations of measures of center.

5. DISCUSSION AND CONCLUSIONS

5.1. PROMOTING INCLUSIVE STATISTICS THROUGH THE SRP-TE

With the design and implementation of the online SRP-TE, we identified conditions that promoted the development of inclusive statistics resorting to digital resources (RQ1). Because we offered an online course, we had the participation of in-service teachers from all the regions in Brazil. This course was only possible by using and integrating several digital resources in all the modules (M0–M4). Proposing an inquiry activity developed from a priori studies and adapted from a school exercise on "distribution of water resources in Brazil" helped promote the transition towards the paradigm of questioning the world by incorporating dimensions of statistical reasoning, literacy, and thinking that do not appear enough in school practices. Moreover, statistics turned out to be a valuable tool to address environmental issues that appeared naturally during the inquiry (M0–M4).

From M0–M2, the SRP-TE was inclusive because of its accessibility, ensuring all teachers interested could participate, regardless of their geographical location. Successful implementation was ensured by integrating real-world issues (Brazilian water resources) and making the use of statistics knowledge relevant to the broader societal and environmental contexts (Stevenson et al., 2013).

Once the inquiry was experienced and analyzed by the participants and educators (M1–M2), the transfer to the classroom was possible, as illustrated by Paola's case (M3–M4). Paola sought to develop an inquiry activity with her sixth-grade students seeking to problematize a social issue that she and her students experience daily. This enabled an inclusive *milieu* to emerge. Given the school's limited infrastructure, Paola used most of the material and digital resources available. In addition, given the case of her three students with reading difficulties, Paola introduced class retakes and supplementary readings that better structured and nourished the inquiry process, thus benefiting all the students. Paola also found that all the students had more difficulties than expected in creating the graphs. The work required to create graphs, however, was strongly motivated by the need to respond to the questions raised. It was thus unavoidable for Paola to devote the time necessary for her students to create and make use of the graphs. It can be said that, by being driven by the logic of the inquiry, the activity naturally became more inclusive, environmental, and "statistical."

The experience with the complete module structure of the SRP-TE showed how "double inclusion" was made possible. On the one hand, the opportunity for teachers from different regions of Brazil to take part in continuing training through participation that was only possible because it was offered remotely. On the other hand, facilitated, was the inclusion of secondary school students (in Paola's case) through the experience of an SRP on water scarcity (adaptation of the one experienced in previous modules) approximating a paradigm of questioning the world. These findings corroborate research undertaken already (Kollosche et al., 2019; Monteiro & Carvalho, 2023; Ni Bhroin & King, 2020; Skovsmose, 2019; Witmer, 2021).

5.2. BREAKING THE TRANSPARENCY OF DATA TREATMENT: CONSEQUENCES FOR THE ECOLOGY OF THE TEACHING OF INCLUSIVE STATISTICS

The online SRP-TE on statistics for in-service teachers made conditions and constraints related to the phenomenon of data treatment transparency visible (RQ2). First, we observed difficulties for the teachers in starting the inquiry of their respective SRP in M1, especially when searching for empirical data, and organizing and analyzing the data. The educators needed to encourage them in much of this work, many times providing more hints and suggestions than initially expected. The online modality did not help, but similar difficulties were found in face-to-face teacher education context (as shown by the pilot study previously implemented). Second, the transparency of statistics knowledge related to data gathering, processing, and reporting emerged strongly. This was evidenced in M2 when the participants did not value some of these aspects when analyzing their inquiry process, and in M4 as exposed in the teacher's comment [x_3: Section 5.1].

These findings reinforce the prevalence of the transparency of the knowledge at stake related to data treatment, which aligns with the results presented by Newton et al. (2011), who highlighted the little importance given by teachers when proposing data collection to their students in statistical processes. Our results aim to take the discussion further and focus more on the unclear *status* of statistical knowledge related to data treatment at school, despite its recent introduction in many countries' curricula. We postulate that taking a broad vision of statistics and data treatment at school requires granting statistics education specific status as part of the "official school mathematical knowledge." Although the SRP-TE implemented showed the difficult challenges ahead to be addressed, we entertain the hope of future developments. The experience of carrying out real inquiries seems necessary for teachers to acknowledge the importance and the elements of data treatment firsthand. It is, however, also important to give statistical ideas and concepts not only visibility but also a more dominant status in school mathematics. Future research should go in this direction to change the school culture and, in particular, provide teachers with epistemological and educational tools to question and build a common understanding of what statistics or data analysis may encapsulate at the school level.

ACKNOWLEDGEMENTS

Funded by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior –Brazil (CAPES)– Finance Code 001 and Spanish R&D project: PID2021-126717NB-C31 (MCIU/AEI/FEDER, UE).

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