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A study and research path for teacher education in statistics: dealing with the transparency of data treatment

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In Brazil, as in many other countries, there is a gap between the type of statistics that pre-service secondary school teachers study at the university and the school statistics they will have to teach in compulsory education. Intending to break this gap, we designed a study and research path for teacher education (SRP-TE) based on the Anthropological Theory of the Didactic that was implemented with a group of in-service secondary school teachers in an online course in Brazil. The SRP-TE addresses the problem related to the transparency of the knowledge to be taught concerning data gathering and processing.

Keywords: Anthropological theory of the didactic, study and research path for teacher education, statistics teaching, teacher education, secondary school statistics.

Introduction

Over the past decades, statistics has strongly evolved in line with the development of technological resources for data processing, resulting in what is known today as “data science” (Holmes, 2017). A review of statistics education research shows the importance of taking a broader view of this field, including aspects such as searching and collecting data in real-world contexts, selecting, organizing, tabulating, and visualizing them, using specific software, simulation, and reporting. All of them directed toward the study of open questions involving variability (Batanero et al., 2011; Burrill & Ben-Zvi, 2019; Garfield & Ben-Zvi, 2008). Bringing this broader perspective into the classroom is no easy task, and it requires at least the complicity of the teaching and teacher education institutions. However, what Felix Klein called the “double discontinuity” between school and university mathematics (Eichler & Isaev, 2022) also seems to apply in the case of statistics.

When considering the kind of statistics introduced to pre-service secondary school teachers, the perspective concerning “dealing with data” as part of the statistical knowledge for teaching varies significantly. For instance, in Brazil, most courses for pre-service secondary school teacher education offer a single subject, *Probability and Statistics*. This subject does not differ from the one proposed for other university degrees like mathematics, engineering, or physics. The subject contents are organised following the logic of the axiomatic construction of concepts about, e.g. descriptive statistics, probability, random variables, models of distributions, inference with one and more samples, simple linear regression and correlation. Therefore, a significant disassociation should be highlighted between the statistics education received at the university and the statistics to be taught at school.

Related to the dominant conception of statistics at the secondary school level, data processing, although it is becoming more and more important in society, still does not have a clear status in secondary school. There, statistical activities are often reduced to numerical calculations of statistical measures (frequencies, means, medians, deviations, quartiles, etc.) and to the elaboration or interpretation of standardized graphical representations (pie or bar charts, histograms and scatter plots) (Batanero et al., 2011; Burrill & Ben-Zvi, 2019). This was already evidenced many years ago by Short and Pigeon (1998) when affirming that, although statistics educators agree that data gathering and analysis steps are valuable, the planning and piloting phases of data collecting are frequently overlooked. Even if recent curriculum guidelines include aspects such as *data collection, organisation and recording, planning and executing a sample survey*, rarely do textbooks include related activities. Using the terminology of Margolinas (2014), we refer to this phenomenon as the *transparency of data processing and analysis* concerning the statistical knowledge to be taught at secondary school (Verbisck et al., 2022).

When considering Klein's double discontinuity and the assign a better place to data processing and management in secondary school statistics, two research questions can be drawn. First, how to evidence the transparency phenomenon in a teacher education context. Second, how to approach it by involving teachers in inquiry processes as instructional activities. In this paper, 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 proposal pursues three main aims: first, getting in-service teachers involved in inquiring into a question that requires the collection and management of quantitative data; second, providing teachers with design tools to adapt and implement a similar activity in secondary school; third, helping teachers approach instructional resources more critically and productively, especially in what concerns the treatment of quantitative data.

Research theoretical framework

Our research is developed within the framework of the Anthropological Theory of the Didactic (Chevallard, 2015) and the tools developed to analyse the paradigm shift in mathematics education, from the currently prevailing *paradigm of visiting works* (PVW) to the *paradigm of questioning the world* (PQW). The new paradigm affects the transformation in mathematics education not only at the pedagogical level, about "how to teach?", but also at the epistemological level, about "what to teach?". In the paradigm of questioning the world, knowledge is learnt during the study and inquiry of relevant questions and appears in the form of dynamic, provisional and collective tools to address them. In this context, data analysis appears as an essential tool for inquiry, whereas in the paradigm of visiting works, only notions and strategies related to the calculation of central and dispersion measures use to seem valued as official statistical knowledge.

To study the conditions needed to transit towards the paradigm of questioning the world, Chevallard (2015) intends a teaching proposal called *study and research paths* (SRPs), which can be described through the *Herbartian schema*: $S(X; Y; Q_0) \rightsquigarrow A^\heartsuit$. This can be considered as a model to design, describe, and analyse any study process (not only in the PQW). A student x (or a group of students X), helped by a teacher y or teachers Y , addresses an initial question Q_0 to 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 “labelled” answers A_j^\diamond , elaborates and adapts them to Q_i , finds new questions during the process which, in turn, call for new answers, and so on. Bosch (2018) points 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_i : $[S(X; Y; Q) \leftrightarrow M_i] \mapsto A^\heartsuit$. This *milieu* is composed of the derived questions Q_i , the “ready-made” answers A_j^\diamond that seem helpful to answer Q_i , works and other objects W_k , and the sets of data D_m of all natures gathered during the inquiry. The extended *Herbartian schema* is symbolized as $[S(X; Y; Q) \leftrightarrow \{Q_i, A_j^\diamond, O_k, D_m\}] \mapsto A^\heartsuit$. The *media-milieu (Me-Mi) dialectic* becomes crucial during the whole SRP. To analyse this dialectic, we look at where external information, data and answers come from, and how their access is managed (*media*). We also ask how they are validated and transformed; and with what materials are the final or intermediate own answers developed (*milieu*). Finally, an SRP is a collective inquiry process during which small groups X_i are generated and individual work is also carried out. X_i and Y_j must organise themselves to work together. To analyse this *individual-collective (I-C) dialectic*, we focus on the roles assumed by X_i and Y_j during the SRP.

The proposal of the SRP was extended to the *study and research paths for teacher education (SRP-TE)* to provide teachers with pertinent (theoretical and practical) tools to nourish and sustain activities close to the paradigm of questioning the world (Barquero et al., 2019). An SRP-TE consists of five modules. *Module 0 (M0)* starts with a professional question (e.g. how to teach proportionality, algebra, or statistics). In *Module 1 (M1)*, the educators let the teachers experience an SRP close to what could exist in their classes and related to the M0 professional question. The experienced SRP is then analysed using epistemological and didactic tools provided by the educators in *Module 2 (M2)*. In *Module 3 (M3)*, teachers design and implement an SRP under specific school conditions to finally, analyse it and share their experiences in *Module 4 (M4)*.

Methodology and the online SRP-TE on statistics for in-service teachers

The methodology follows the didactic engineering research principles applied to the SRP-TE (Barquero & Bosch, 2015). They consist of four major steps. The first step is to identify the didactic phenomena to be addressed. In our case, it corresponds to the transparency of knowledge related to data treatment at the secondary school level. The second step (the *a priori* analysis) 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. The third step is the implementation, observation, and *in vivo* analysis of the activity. Finally, the fourth step is the *a posteriori* analysis based on the validation of the teacher's educational activity, as well as the development of knowledge about the initially identified didactic phenomenon.

Our case study focuses on an SRP-TE implemented as an online modality course from September to December 2022 for in-service secondary school teachers in Brazil (voluntary participation). 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 assume some after-class work, especially to implement a teaching proposal some weeks in November/December and, in the end, 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 all

together. *Microsoft Teams* was also used as a document repository. A *Whatsapp* group with all educators and students supported the exchanges, especially between sessions. All *Teams* sessions were recorded. The data gathered include educators' and teachers' productions and the transcripts of their exchanges in the course sessions. In this paper, we analyse the teachers' behaviour during the different modules of the course, paying special attention to the difficulties found in using the ATD tools introduced to describe, design and implement inquiry processes related to data treatment. In fact, we will interpret these difficulties as constraints coming from the prevailing paradigm of visiting work and the related phenomenon of transparency of data treatment in secondary school mathematics.

In M0, our Q_{0-TE} was about *How should we teach statistics in secondary school?* In this module, the educators presented Q_{0-TE} as a cross-cutting issue in all other modules. Our didactic system was composed of three groups working in parallel and carrying out different SRP under the guidance of three educators. Group 1 is the only one considered in this paper. It was composed of five in-service teachers, working in lower secondary education, coordinated by the first author of this article (y_1) and the other authors as observers. The initial generating question Q_{0-SRP1} was about a *newspaper headline about "Brazil has lost 15% of its water resources in 30 years, a loss of almost twice the water surface area of the entire Northeast"*. *How to analyse the veracity of this news?* 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, as shown in Table 1.

Table 1: Organisation and structure of the SPR-TE sessions

Sessions	Description of the work	Room
1 st : 3/09/22 M0 (2 parts)	Researchers introduced the course (modules, chronogram, group dynamics). <i>PVW and PQW were introduced.</i>	General
	Participants elaborated professional questions on a <i>Padlet</i> . General discussion and organisation according to the different paradigms.	
2 nd : 10/09/22 M0-1 (2 parts)	Researchers reintroduced the course and the paradigms: PVW and PQW.	General
	Q_{0-SRP} was proposed by coordinators in each X_i . Teamwork on specifics Q_{0-SRP} : elaboration of other questions, searching on the internet. <i>Q-A dialectic introduced.</i>	Groups Room
3 rd : 17/09/22 M1 (2 parts)	Coordinators of each X_i shared the derived questions of their respective Q_{0-SRP} .	General
	Inquiry into Q_{0-SRP1} and Q_i : finding a database and working with data in <i>Excel</i> .	Groups Room
4 th : 24/09/22 M1 (2 parts)	Researchers' intervention in the aspects of data treatment and the Brazilian secondary education curriculum. Coordinators of each X_i shared the data.	General
	Study on specifics Q_{0-SRP} and Q_i : elaborating A^\heartsuit to Q_{0-SRP} .	Groups Room
5 th : 1/10/22 M1-2 (2 parts)	Finalisation of A^\heartsuit to Q_{0-SRP} . And, elaboration of a <i>Q-A map</i> on a <i>Padlet</i> .	Groups Room
	One participant of each X_i presented their A^\heartsuit to Q_{0-SRP} to the whole group.	General
6 th : 8/10/22 M2 (2 parts)	Researchers introduced the <i>Herbartian schema</i> , <i>Me-Mi dialectic</i> , and <i>I-C dialectic</i> as didactic tools to analyse the SRP each X_i experienced.	General
	Collective analysis of the SRP experienced, using the didactic tools introduced.	Groups Room
7 th : 15/10/22 M2-3 (2 parts)	Coordinators of each X_i shared and discussed their analyses.	General
	Design and adaptations of an SRP to be implemented in the real classroom.	Individual work
8 th : 22/10/22 M3	Collective design and adaptations of an SRP to implement in the classroom.	Groups Room
9 th : 5/11/22 M3 (2 parts)	Researchers introduced the notion of <i>didactic contract</i> .	General
	Finishing the collective design of an SRP to implement in the classroom.	Groups Room
10 th : 2/11/22 M3 (2 parts)	One participant of each X_i presented the SRP designed.	General
	Teamwork on the activity: "From a school exercise to an SRP".	Groups Room

11 th : 19/11/22 M3 (2 parts)	Participants x_1 and x_2 shared the first lessons they implemented during the week. Teamwork on the activity: “From a school exercise to an SRP”	General Groups Room
12 th : 26/11/22 M3-4 (2 parts)	Participants x_1 and x_2 shared the further lessons implemented during the week; participant x_3 shared the first lessons implemented during the week. One participant of each X_i presented the SRP designed in the activity “From a school exercise to an SRP”.	General
13 th : 3/12/22 M4	Each participant started to elaborate a final report.	Individual work
14 th : 10/12/22 M4 (2 parts)	Participants x_1 , x_2 , and x_3 shared the finalisation of the SRP implemented in class. Collective <i>a posteriori</i> analysis, final discussions.	General

Results and discussion of the SRP-TE on Brazil's water resources

The generating question Q_{0-SRP1} presented to Group 1 comes from a previous research work presented in Verbisck et al. (2022), where we carried out an *a priori* analysis of an SRP-TE that starts from a school activity about water resources in Brazil. 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 from secondary education, such as the search, collection, cleaning, and representation of data. In M1, y_1 proposed to begin with a Brazilian newspaper related to water resources: “Brazil has lost 15% of its water resources in 30 years, a loss of almost twice the water surface area of the entire Northeast”. Q_{0-SRP1} was about *How to analyse the veracity of this news?* The maps of questions-answers were presented to the in-service teachers as a tool for analysing the development of the inquiry process. Initially, the team raised many questions, however, they chose some of them to search for answers:

Q_{1-SRP1} : What data are presented in the news?

$Q_{1.1-SRP1}$: Are there official databases that provide these data? Can we access these data?

$Q_{1.2-SRP1}$: What information can we get from it (the database)?

$Q_{1.2.1-SRP1}$: How are the data from this official database produced?

$Q_{1.2.2-SRP1}$: Which data do we use to perform the analysis?

Q_{2-SRP1} : How can we corroborate the diagnoses mentioned in the news story?

$Q_{2.1-SRP1}$: What is the water situation of each Brazilian region?

In the corresponding answers to $Q_{1.2.2-SRP1}$, Q_{2-SRP1} , and $Q_{2.1-SRP1}$, the group downloaded the data from the *MapBiomass* database (the one presented in the news) and worked with *Excel*. To elaborate A^\heartsuit , they organised the data from (1985 to 2020) into a table and constructed bar graphs and line graphs of the five Brazilian regions to make the comparisons among losses. They were unsure about the main tools to elaborate tables and graphs. They also had difficulties in choosing between a bar graph or a line graph to represent these data. They raised some questions concerning these difficulties:

$Q_{Construction\ of\ tables}$: What are the main elements of a table?

$Q_{Statistical\ graphs}$: What type of graphs to choose to represent the data? What are the main elements of a graph? Is it better to construct bar graphs or line graphs to represent this data? Why? Series graphs take different values, how to compare?

Four sessions were set aside for the development of this SRP and we (researchers) were already aware that it would not be enough time to investigate in depth all the issues raised. The aim of M1 was for in-service teachers to realize, albeit superficially, how an inquiry activity based on an SRP can work.

In M2 with the analysis of the SRP, the main discussion was about the statistical knowledge used for the elaboration of A^\heartsuit . The group pointed at the *construction of the table with data, the construction of graphs, comparisons of loss in percentages, and the calculation of the annual variation (absolute and in percentages)*. We might notice here how much of the previous work—database search and access and its organization—was not considered part of the statistical knowledge. In M3, a teacher x_1 volunteered to implement an SRP with sixth-grade students (aged 11-12). She was interested in working on the topic of rainfall levels in the region (*Agreste – Northeast of Brazil*). She found a newspaper article entitled “Pernambuco decrees emergency due to drought in 61 cities of *Agreste*”. So, participants worked on the a priori design of an SRP that took this news as a starting point for the Q_0 : *What is an emergency about drought? When is it decreed?* The teacher implemented this SRP over three weeks, with a total of nine hours. In her class, the 26 students were organized in pairs or triads. In the first session, the class carried out a collective reading of the text (newspaper), the teacher formulated Q_0 and the students, working in groups, began to elaborate new questions Q_i :

- Q_0 : What is an emergency about drought? When is it decreed?
- Q_1 : What are the water sources in our region? What is the name of the river that runs near the school (Pesqueira town)?
- Q_2 : Are the waters from rivers and wells drinkable?
- Q_3 : Where is the town of Salgadinho?
- Q_4 : What are the rainfall levels in our region?

In the second class, the students searched different websites to elaborate answers A^\diamond_j to Q_i . Students incorporated some A^\diamond_j into their *milieu* and wrote down the “source” in which they found the answer because the teacher told them to mention it. In some moments, students also used the teacher as a media, writing in one of the answers: “source: the teacher”. Question Q_4 prompted the teacher to hand out a table with data on average monthly rainfall for the town where the students live and for eight surrounding towns. These data were collected from an online database. So, to seek answers to Q_4 , pairs and triads began to construct bar graphs of the nine cities they had selected (guided by the teacher). In the following lessons, with these data, students mainly considered bar graphs. The teacher noticed that students had difficulties constructing the graphs, as she believes this is the first time they had elaborate graphs on their own. In the last two lessons, she proposed a final analysis of the graphs, guided by the questions: *What comparisons can we make between the graphs? Which months are there less rainfall in the municipalities observed? What conclusions can be drawn?*

In M4, we had the opportunity to share comments about this experience. Participants with educators jointly analysed the implemented SRPs. We could identify how the teacher succeeded in managing the different dialectics of the inquiry process. In the case of *Q-A dialectic*, when she proposed an initial question to start the inquiry and encouraged her students to investigate by elaborating on other questions and searching for answers in different media. For the *Me-Mi dialectic*, she mobilised different media, such as the internet, maps of the region or a database that she pre-selected. All these elements are achieved to incorporate new objects into their *milieu*. As for the *I-C dialectic*, she tried to work on a different classroom dynamic: organising students in pairs and trios, proposing to go to the technology room, as well as collective graph constructions. And she tried to adopt a new role and responsibilities in guiding the inquiry process without giving the answers to students’ questions.

Finally, we notice a critical episode in the course that highlights the strength of the phenomenon of *data treatment transparency* that the SRP-TE could not really overcome. It appeared in the comment of another participant x_3 regarding the implementation of x_1 :

x_3 : What you did seems interesting, but *statistics* is something different because it is about data analysis, the calculation of measures of central tendency, and even more so. But you [x_1] didn't have the opportunity to do this part which, in my opinion, is the most important.

Although x_1 's students elaborated several graphs and used them as relevant means to extract information about the question addressed, interpreting, comparing graphs, and summarising conclusions, x_3 expressed once more the transparency of these aspects in statistical activity.

Conclusion

The online SRP-TE on statistics for in-service teachers made visible some conditions and constraints related to the phenomenon of data treatment transparency. First of all, we observed difficulties for the groups in starting the inquiry of their respective SRPs in M1, especially when searching for empirical data and organising and analysing them. The educators needed to encourage the participants in much of this work, many times providing more hints than were initially expected. The online modality did not help, but similar difficulties are found in face-to-face teacher education (as it is being implemented at this moment). Second, the transparency of statistics knowledge in what concerns data gathering, processing, and reporting emerged strongly. In M2 when participants did not value some important aspects when analysing their work in the SRP (e.g. the collection of data in a dataset and its organization), or in M4 as we saw in one example of a teacher's comment [x_3]. The exception of the teacher x_1 with her students is a piece of hope and motivation to go on with the research.

These findings reinforce the prevalence of the transparency of the knowledge at stake related to data treatment, in alignment with the results presented by Newton et al. (2011) who highlight the little importance given by teachers when proposing data collection to their students in statistical processes. Our results aim to bring the discussion further and focus more on the unclear *status* of mathematical knowledge related to data treatment in teachers' (and consequently students') knowledge and know-how, despite its recent introduction in many countries' curricula. We postulate that bringing to school a broad vision of statistics and data treatment requires granting it a specific status as part of the "official school mathematical knowledge". Although the implemented SRP-TE evidences the difficult challenges we might address, it also opens some lines of hope and future development. What seems totally necessary from statistics education is that we (researchers and educators) provide tools that give visibility and a clearer status to data treatment in mathematics school teaching, as it would not be enough that the curricula include the stages of the statistical cycle. Future research should go in this direction to change the culture and, in particular, provide teachers with epistemological and didactic tools to question and build a common "understanding" of what statistics is.

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