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Technological choices in Statistics: reflections on pedagogical practices in the Brazilian higher education

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Abstract: Our study analyzed the integration of digital technologies into Statistics teaching by exploring professors' perceptions and practices in the Brazilian context. We investigated educators' technological choices through descriptive statistical techniques and multivariate analysis, highlighting the relation among professors' Education processes, pedagogical practices and the use of digital technologies. Our results, which showed the influence of professors' Education processes on their technological choices, were discussed in the light of statistical literacy and the TPACK model. The study points out the crucial role of professors' Education processes in critical and intentional integration of technology into teaching and provides valuable reflections on contemporary Statistics Education in Brazilian Higher Education.

Keywords: Statistics Education. Digital Technologies. Professors' Education Processes. Statistical Literacy. TPACK.

Opciones tecnológicas en Estadística: reflexiones sobre las prácticas pedagógicas en el contexto universitario brasileño

Resumen: Neste artículo analizamos la integración de las tecnologías digitales en la enseñanza de la estadística, explorando las percepciones y prácticas de los docentes en el contexto brasileño. Investigamos las elecciones tecnológicas de los educadores a través de técnicas estadísticas descriptivas y análisis multivariado, destacando la relación entre la formación docente, las prácticas pedagógicas y el uso de tecnologías digitales. Como resultados, identificamos la influencia de la formación de los docentes en sus elecciones tecnológicas y discutimos los resultados a la luz de la Literacia Estadística y el modelo TPACK. El estudio ofrece consideraciones sobre el papel crucial de la formación docente en la integración crítica e intencional de la tecnología, proporcionando reflexiones valiosas para la educación estadística contemporánea en el escenario universitario brasileño.

Palabras clave: Educación Estadística. Tecnologías Digitales. Formación de Profesores. Literacia Estadística. TPACK.

Escolhas tecnológicas em Estatística: reflexões sobre práticas pedagógicas no contexto universitário brasileiro

Resumo: Neste artigo analisamos a integração de tecnologias digitais no ensino de estatística, explorando as percepções e práticas de professores no contexto brasileiro. Investigamos as escolhas tecnológicas dos educadores por meio de técnicas estatísticas descritivas e análise multivariada, destacando a relação entre formação docente, práticas pedagógicas e uso de tecnologias digitais. Como resultados identificamos a influência da formação dos docentes em suas escolhas tecnológicas, e discutimos os resultados à luz do Letramento Estatístico e do modelo TPACK. O estudo oferece considerações sobre o papel crucial da formação docente na integração crítica e intencional da tecnologia, proporcionando reflexões valiosas para a educação estatística contemporânea no cenário universitário brasileiro.

Palavras-chave: Educação Estatística. Tecnologias Digitais. Formação Docente. Letramento Estatístico. TPACK.

1 Introduction

Technology may be a powerful tool to transform learning since it has the potential to empower students to broaden their experiences and go beyond traditional class boundaries. It happens when self-directed learning is supported and educators are helped to adapt learning experiences to students' individual needs. Besides, technology has the potential to foster collaboration between students and educators globally and enables them to creatively express what they have learned.

To make these possibilities come true, educational processes must evolve. Pretto, Bonilla and Sena (2020, p. 10) have a fundamental perspective of the transformation which highlights the need for changes in the educational scenario. According to them, "yesterday's models are not good anymore"; it shows the pressing need to develop innovative and adaptable methods which are able to meet current demands. This view triggers deep reflection on the importance of re-evaluating and re-designing educational processes which acknowledge both the dynamics of the society and the increasing intersection of Education and digital technologies.

In the field of Statistics, teaching acquires additional nuances since educators need not only sound comprehension of statistical concepts but also significant approximation to concepts that contribute to digital literacy. To integrate digital technologies with the curriculum means to go beyond mere comprehension of Statistics; it is essential to review fundamental statistical concepts with the use of the potential of technology to improve the process of teaching and learning (Magalhães, 2014).

The need to change the focus was already noticeable in a round table on *Technology in Statistics Education* run by the International Association for Statistical Education (IASE) in 2012. In that meeting, Gould (2012) highlighted that, despite significant transformations in the educational scenario in the last decade, discussions were still mainly centered on the functionality of statistical software and possibilities of remote teaching. Batanero (2019) pointed out that it keeps being a concern and emphasized the pressing need to carry out more studies of professors' and students' effective use of digital technologies in class.

In this context of interactions, Gomes, André and Morais (2023) highlighted the importance of connections between objects of mathematical knowledge and dissemination of the use of digital technologies, which we also expand to statistical knowledge. This approach has become increasingly vital, mainly the urgent need to effectively integrate Mathematics and/or Statistics with technological innovations to enrich and improve the educational process.

In the current educational scenario, challenges have been posed to the process of pedagogical mediation since mere digitalization of analogic processes is not coherently aligned with collaborative and convergent educational practices powered by technologies, as highlighted by Gomes and Carvalho (2020). Historically, Education has been marked by digital technologies guided by technicist comprehension limited to its use. We have currently had the opportunity of appropriating technologies to foster protagonism, authorship, autonomy, criticality and collaboration based on pedagogical strategies.

Considering Tardif's postulate (2014) that knowledge is also constituted of practice and incorporating the concept of reflexive knowledge proposed by Shulman (1987), which enables teachers to do/undo/redo pedagogical choices throughout their teaching aligned with the need, emphasized by Mishra and Koehler (2006), for formal inclusion of digital technologies into educational processes, innovative and transformative possibilities emerge. These opportunities are achieved when Digital Information and Communication Technologies (DICT) are understood and effectively applied to knowledge construction, thus, leading to emancipatory educational practices (Filatro & Cavalcanti, 2018). This focus not only broadens the traditional approach but also develops educators' skills to design dynamic learning experiences aligned with current demands. Convergence of these fundamental principles enables the conception of a more inclusive and participatory environment aimed at students' comprehensive development.

Therefore, this study aims at reflecting on Statistics professors' decision-making processes in Brazilian Higher Education regarding their technological choices in their pedagogical practices. We investigated the factors that may influence their choices with the use of descriptive statistical techniques and multivariate analysis to have a broad understanding of collected data. An online questionnaire was answered by 249 professors who represent 98% of Brazilian public universities and 25 other institutions.

The following sections provide a detailed immersion in different aspects that involve Statistics professors' decision-making processes in Brazilian Higher Education regarding their technological choices in their pedagogical practices. We start by exploring the concept of statistical literacy, followed by an analysis of features of Modern Statistics. Afterwards, we investigate conceptions of teaching and the relevance of digital literacy to professors. Then, we describe the methodology that we used in this study and introduce and discuss its results thoroughly. The conclusion consolidates the findings and shows ways that may be followed by research into the intersection of Education and digital technologies.

2 Statistical Literacy

Statistical literacy, which has emerged as a crucial competence in the current educational and social scenario, is permeated with a huge volume of data and the need for decision-making processes based on information. According to Gal (2019), this concept transcends mere comprehension of statistical formulas; on the contrary, it encompasses the critical skill to interpret information and contextualize it in real world situations. In a world that has been increasingly saturated with data, this competence is essential for both students and professors since they need to interpret data routinely to understand and participate in the society actively.

Statistical literacy is not restricted to become a mere subset of formal Statistics or of Mathematics teaching. On the contrary, it is a distinct competence, full of singular elements which have often been neglected (Gal, 2019). According to Moore (1992), Statistics is a mathematical science but it is not merely a branch of Mathematics; it constitutes an autonomous course. Its autonomy is seen in the influence of the context on Statistics since data are conceived, not only as numbers but also as entities rooted in their context. Other issues that must be considered are the multifaceted complexity and indetermination inherent to statistical problems, such as variability, randomness and uncertainty, which contrast with precision traditionally attributed to other mathematical domains.

The model of statistical literacy proposed by Gal (2002) emphasizes ideas related to knowledge about the context. Afterwards (Gal, 2019), the author highlights the importance of a significant and relevant context by introducing two constraints: authenticity, i. e., the context must take place or be feasible in the real world, and “the context must awake real need for knowledge” (Gal, 2019, p. 5).

In this scenario, courses offered by undergraduate programs are expected to meet these conditions by using potentially real data related to the field of knowledge. Besides, it is fundamental to trigger students’ curiosity regarding problems resulting from real needs identified by research in their field of interest. Thus, the aim is to integrate statistical knowledge with comprehension of the context to enable a broad and applied approach.

Courses in Statistics offered by undergraduate programs in Brazilian Higher Education institutions are set out, either objectively or not, by the National Curriculum Guidelines and by the graduate’s profile established by Pedagogical Projects of Undergraduate Programs. Thus, objectives of courses in the field vary in accordance with their undergraduate programs. On the other hand, we believe that they should be a part of students’ statistical literacy process which starts in Basic Education. In this scenario, signification of real data to understand the context and decision-making processes give room to the inclusion of digital technologies in their process of analysis and comprehension. It goes beyond the mere functional nature of technologies and enables them to be used as an extension of the cognitive process.

Therefore, development of statistical literacy is not isolated; it is part of the comprehension process and application of the new Statistics which we consider Modern Statistics. It is defined and discussed in the next section. This scenario challenges educators not only to construct knowledge but also to foster contextualized practices so as to connect theory and application in the digital era and contribute to people’s development to face challenges posed by a data-driven society.

3 Modern Statistics

Modern Statistics, whose advanced techniques have been applied to interpret and attribute significance to data, is a dynamic field which keeps evolving (Wasserman, 2004). In the current scenario with a huge volume of data under analysis, Statistics plays a crucial role in data extraction and knowledge construction based on them since the skill to understand data and reason based on them is highlighted by Gal (2019) as a fundamental requirement for statistical literacy.

A distinctive feature of Modern Statistics is its close relation with computational thinking (Ainley *et al.*, 2015; Biehler, 1990; Gould, 2021; Hastie *et al.*, 2001). Popularization of computing enables Modern Statistics to use the capacity for processing large data sets; thus, sophisticated methods and specialized tools may be easily employed.

In addition to traditional methods, such as hypothesis testing, Modern Statistics has incorporated advanced approaches, such as regression models, multivariate analysis and machine learning (Hastie *et al.*, 2001). These techniques reveal complex patterns, identify causal relations and trigger valuable insight.

Some researchers, such as McNamara (2018), Batanero (2000), Ben-Zvi (2019) and

Garfield (2008), have contributed to Modern Statistics by focusing on the use of digital technologies in teaching processes. Their studies have highlighted integration of digital technologies into statistical teaching and have gone beyond technical aspects to face current challenges. In sum, Modern Statistics has adapted to current demands by employing technological advances and cutting-edge techniques in data analysis and by playing an essential role in informed decision making.

4 Conceptions about the Teaching Profession

In their practice, teachers confront several situations that require mobilization, construction and reconstruction of knowledge which intertwines the process of teaching and learning in class. In this context, contributions given by some authors, such as Tardif (2014), should be highlighted. He defines teaching knowledge as a plural one, composed of a quite coherent fusion of knowledge derived from professional development, courses, curricula and experiences. The author crucially distinguishes knowledge acquired in teaching practices (experiential knowledge) from knowledge resulting from teacher Education programs (professional knowledge).

> Teachers believe that their knowledge is deeply anchored in their life experience at work. It does not mean that teachers do not use external knowledge derived from, for instance, their Education, research, programs or other sources. However, it means that external knowledge is reinterpreted in the light of specific needs at work. (Tardif, 2013, p. 568)

Shulman (1987) collaborates with another perspective on teaching knowledge since he introduced the concept of Pedagogical Content Knowledge (PCK), which represents the idea of integration of content knowledge into pedagogical strategies, taking into consideration students' conceptions and difficulties in an attempt to ensure learning. The author points out not only the importance of content knowledge but also the comprehension of the importance of adapting the content to make it more accessible and comprehensible and bring it closer to students so that they may learn.

According to Shulman (1987), categories of knowledge that teachers need are: Content Knowledge, which refers to deep understanding of the subject they teach; General Pedagogical Knowledge, which involves comprehension of general teaching theories and practices, such as class strategies, time management and evaluation; and Pedagogical Content Knowledge (PCK), which Schulman considers the core and refers to teachers' capacity for dealing with the content to make it accessible and comprehensible to students, including specific strategies to teach complex concepts.

> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates. (Shulman, 1986, pp. 9-10)

In addition to the three previously mentioned categories, there are Curricular Knowledge, which involves understanding school curricula, educational patterns and guidelines to help teachers align their practices with what is expected by educational institutions, Knowledge of Learners, which is the comprehension of students' characteristics, needs and learning styles — it enables teachers to adapt their approach to meet different needs —, Knowledge of Context, which is understanding of the environment in which teaching takes place, including cultural, social and institutional factors that may influence the educational process, and Reflective Knowledge, which is the skill to reflect on the pedagogical practice by continuous evaluation of the impact of teaching strategies and search for ongoing improvement.

In the light of Shulman's ideas and the insertion of DICT in the educational process, we propose the theoretical model of Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006; Koehler & Mishra, 2009). This structure expands the dimensions proposed by Shulman since it goes beyond the idea that teachers must necessarily be experts in technology and brings up the discussion about the formalization of inclusion of DICT in educational processes.

In TPACK, teachers are expected to understand how concepts may be represented with the use of technologies. Thus, teachers must be able to find pedagogical alternatives that, together with the use of technologies, enable students to achieve or broaden their comprehension of complex concepts, overcome learning difficulties and understand how technologies may be used for developing or strengthening epistemologies. In sum, TPACK is

> integrated knowledge that enables educators to implement technology effectively and appropriately to improve learning and teaching. It is a useful structure to understand and describe teachers' need for knowledge to effectively integrate technology. (Mishra & Koehler, 2006, p. 1029)

We reflected on Shulman's conceptions, which were later broadened by Mishra and Koehler, and created the context in which Statistics professors' actions in Higher Education must have:

a) Curriculum knowledge: to know where and why one teaches, regarding adherence to pedagogical projects in institutions and programs in which one works;

b) Content knowledge: to master contents in Statistics to be able to teach effectively and make them easier for students to understand;

c) Knowledge of learners: to understand who students are and their specificities, as much as possible, considering institutional constraints and difficulties;

d) Pedagogical knowledge: to deeply understand pedagogical practices and theories and address and make content learning easier;

e) Reflective Knowledge: to continuously evaluate teaching practices and do/undo/redo pedagogical choices throughout the teaching process;

f) Digital literacy: to deeply explore available digital technologies in agreement with Modern Statistics.

As mentioned before, to use digital technologies intentionally and consciously, we need digital literacy, which is defined in the following section.

5 Digital Literacy

Several scholars, such as Lankshear and Knobel (2008), List, Brante and Klee (2020) and Freitas (2010), have contributed to enrich the concept of digital literacy. We decided to address digital literacy from the perspective which is based on integration among instrumental, cognitive and social aspects, as described below.

> [...] I see digital literacy as the set of competences needed to help people understand and use information critically and strategically in different formats, deriving from several sources presented by computers and internet to enable them to reach objectives that are often shared socially and culturally. (Freitas, 2010, pp. 239-240)

Thus, digital literacy is not merely an isolated competence but the set that integrates instrumental, social and cultural competences which ensure access to science, technology, culture and work, thus, promoting autonomy and criticality, in alignment with Gal's assumptions (2002, 2019). List *et al.* (2020) reinforce this idea and argue that the concept of digital literacy goes beyond technical and cognitive dimensions of learning and incorporates the socioemotional one. This dimension encompasses aspects of comprehension, use and development of DICT and enables not only access and dissemination of information but also critical, ethical and responsible production of knowledge. The importance of learning how to work collaboratively and cooperatively in an organized way should also be highlighted.

In the context of Statistics teaching in undergraduate programs, it does not seem feasible to ignore technological alternatives which may collaborate and complement pedagogical practices. Thus, instrumental aspects of the conception of digital literacy must be ensured. It should be mentioned that knowing these alternatives does not necessarily imply deep knowledge of every tool but the capacity for identifying its potentialities and limitations and for evaluating its relevance to the program. According to Shulman (1987), this choice must be based on adherence and pedagogical intentionality that considers the context in which professors work.

As mentioned before, considering that professors teach Statistics in the modern conception, one of the crucial elements is the volume of data, their relevance to the real world and their reliability. Thus, professors must try to develop not only students' cognitive aspects but also socioemotional ones related to digital literacy, aligned with Gal's proposals for statistical literacy (2002, 2019). It implies that students have opportunities to evaluate data critically, interpret them consistently and disseminate them ethically and responsibly.

Another crucial issue is students' digital literacy. Even though they are immersed in DICT from an early age, immersion itself does not ensure all aspects previously described by digital literacy. However, it enables professors to explore and redefine knowledge brought by students to their fields. As a result, professors contribute to re-organize teaching practices and encourage students to use all facets of digital literacy.

6 Methodology

Data were collected by an online questionnaire which featured questions that were in the scope of the project entitled "Integration of Digital Technologies into Statistics Teaching: Professors' Perceptions and Practices in the Brazilian Context". Even though the original questionnaire had a large number of questions, we decided to choose the ones that enabled to analyze results to meet the objectives of our study. The project was approved by the Research Ethics Committee (n. 6.470.293).

We sent online invitations to professionals who work in the field (Statistics professors) in Higher Education institutions all over Brazil. We chose the online approach to optimize participation and efficiency in data collection. Besides, participants would feel free to answer the questions anytime. Online invitations encouraged professors to share their perceptions and experiences to contribute to our study.

Data used for the analysis comprised several variables, such as age, sex, length of teaching experience, undergraduate program and post-graduate program in Statistics. Besides, information on the use of software programs in professors' teaching practices was also collected. All variables were carefully selected to enable a comprehensive analysis of Statistics professors' demographic, academic and technological characteristics.

Data were analyzed by descriptive statistical techniques which led to comprehensive understanding of resulting answers. In addition, we applied the Multiple Correspondence Analysis (MCA) to explore relations among categorical variables and provide deeper insight into data patterns and associations.

The MCA, an exploratory and predictive multivariate statistical technique (Bertoncelo, 2022), is able to deal simultaneously with multiple variables and to investigate associations among different categorical variables effectively (Husson *et al.*, 2017). This approach enables us to examine, in an exploratory way, relations among types of categorical variables by visually representing them in a two-dimensional space. Besides, it offers a predictive dimension since it reconstructs the structure of affinities among the types and enables projection of individuals on the two-dimensional plane. The projection enables to analyze how individual properties are correlated to the structure (Bertoncelo, 2022).

The MCA was carried out by the FactoMineR package (Lê *et al.*, 2008). In the analysis, original data were transformed into two-dimensional correspondence plots so that relations among categories could be effectively visualized. Data and scripts used in this analysis are available at https://doi.org/10.5281/zenodo.10635137, together with the report generated by the analysis tool.

7 Results

Our sample is composed of professors who have taught courses in Statistics in undergraduate programs in Higher Education. The sample is unidentifiable to protect confidentiality. This selection resulted from a list of professors compiled with public data available in institutional sites and with names of other professors suggested by participants. E-invitations were sent to 2,716 professors in all 68 public federal universities, 39 (out of 41) public state universities (95%), all 5 public city universities and 25 different institutions. All of them are Brazilian institutions.

The e-invitations led to 249 valid answers: 84 (33.73%) were answered by female professors while 165 (66.27%) were answered by male ones. Table 1 and Figure 1 show a detailed analysis of professors' ages which is also segmented by sex.

Table 1: Participants' ages

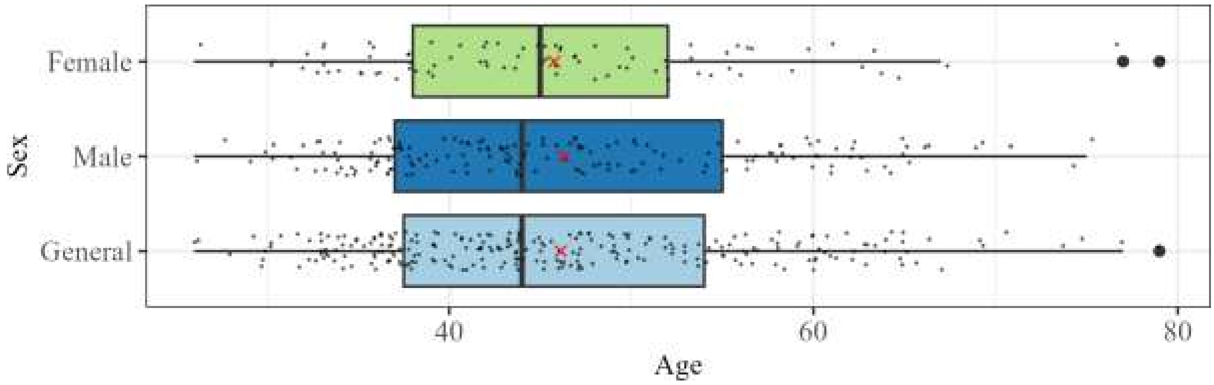
Sex	F_i	%	Minimum	Q_1	Median	Mean	Q_3	Maximum	Void
Female	84	33.73	26	38.0	45	45.8	52	79	1
Male	165	66.27	26	37.0	44	46.3	55	75	1
General	249	100.00	26	37.5	44	46.1	54	79	2

Source: Research data

Regarding data on female professors, the minimum age was 26 years and the maximum one was 79. The median, representing the midpoint of distribution, is 45 years while the mean is 45.8. Concerning male professors, ages ranged from 26 to 75 years; median is 44 years and the mean is 46.3 years.

When we applied the Shapiro-Wilk test to the variable age segmented by sex, we observed that both the female group (W = 0.9604, p-value = 0.0119) and the male one (W = 0.9584, p-value < 0.001), results showed non-normal data distribution. When we applied the Mann-Whitney test to compare both independent samples, we did not find any statistically significant evidence to state that sex has any effect on age (W = 6656.5, p-valor = 0.7786). It suggests that, based on available data, there is no significant difference in ages between both sexes.

Figure 1: Participants' age



Source: Research data

Table 2 and Figure 2 show professors' length of teaching experience (expressed as years), segmented by sex.

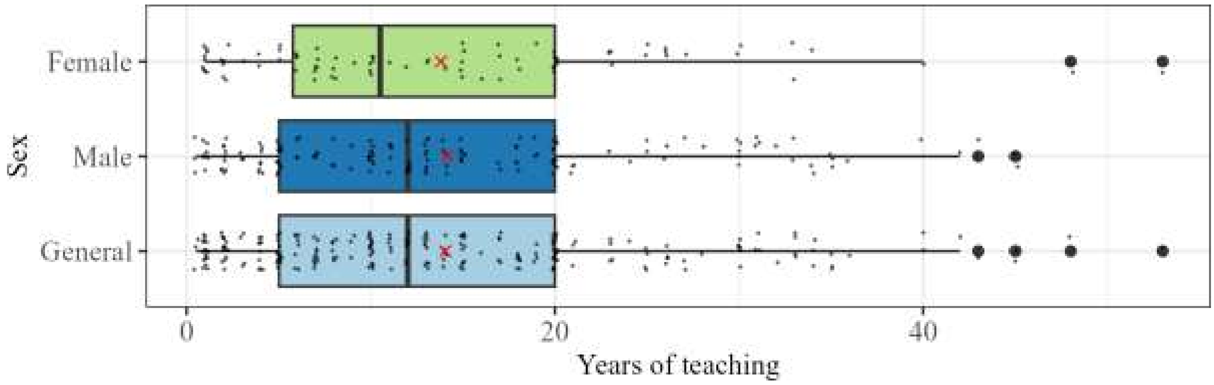
Table 2: Participants' years of teaching

Sex	Minimum	Q_1	Median	Mean	Q_3	Maximum
Female	1.0	5.75	10.5	13.80	20	53
Male	0.5	5.00	12.0	14.15	20	45
General	0.5	5.00	12.0	14.04	20	53

Source: Research data

The analysis of the length of teaching experience of female professors showed that the minimum number of years is 1 year while the maximum one is 53 years. The median is 10.5 years and the mean is 13.8 years. Regarding male professors, it ranges between 0.5 and 45 years. The median is 12 years and the mean is 14.15 years.

Figure 2: Participants' years of teaching



Source: Research data

We applied the Shapiro-Wilk test to the variable length of teaching experience segmented by sex and observed that, for both the female group (W = 0.9055, p-value < 0.001) and the male group (W = 0.9198, p-value < 0.001), results showed non-normal data distribution. When we applied the Mann-Whitney test to compare both independent samples, we did not find any statistically significant evidence to state that sex has any effect on the length of teaching experience (W = 6729, p-value = 0.7087). It suggests that, based on available data, there is no significant difference in length of teaching experience between both sexes.

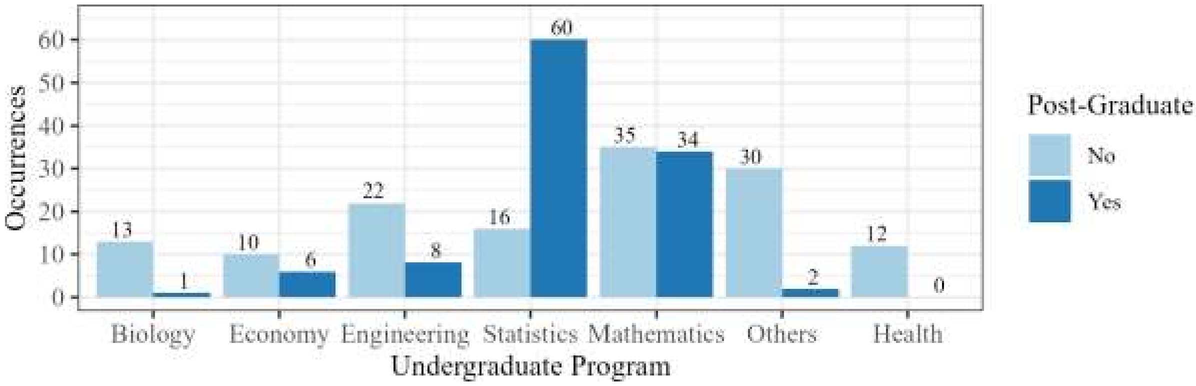
We also investigated participants' undergraduate programs. To simplify the analysis, we grouped them into categories. The ones that did not occur more than 10 times were grouped into the category "others". To deepen our comprehension of professors' Education processes, we also investigated whether they had taken any post-graduate program in Statistics. Data are shown in Table 3 and in Figure 3.

Table 3: Professors' Education processes

Undergraduate Program	General		Without post-graduate program in Statistics		With post-graduate program in Statistics	
	F_i	%	F_i	%	F_i	%
Biology	14	5.6	13	5.2	1	0.4
Economy	16	6.4	10	4.0	6	2.4
Engineering	30	12.0	22	8.8	8	3.2
Statistics	76	30.5	16	6.4	60	24.1
Mathematics	69	27.7	35	14.1	34	13.7
Others	32	12.9	30	12.0	2	0.8
Health	12	4.8	12	4.8	0	0.0
Total	249	100.0	138	55.4	111	44.6

Source: Research data

Figure 3: Professors' Education processes



Source: Research data

The analysis of Table 3 shows significant results of professors' Education processes. It should be highlighted that professionals from different fields of knowledge teach courses in Statistics. It shows the relevance of the course in several academic contexts since not all professors are mathematicians and statisticians. Only 30.5% graduated in Statistics, while 27.7% graduated in Mathematics and 41.8%, in other fields. In addition, 44.6% attended post-graduate programs in Statistics, whereas 55.4% did not.

When we deepened the analysis of professors who had attended post-graduate programs in Statistics, we noticed that the ones who had graduated in Statistics or Mathematics were prone to attend specialization programs, i. e., 94% of professors that belong to this group had attended post-graduate programs in Statistics. It should be pointed out that the other academic areas only represent a small group since few professors who graduated in other fields search for post-graduate programs, even though they teach courses in Statistics. This dynamics reveals not only the transversality of specialization programs in Statistics but also the diversity of professors' undergraduate programs, thus, contributing to a multifaceted approach to Statistics teaching.

Our last variable of interest addresses the categories of software programs used by professors in their educational practices. Due to the diversity mentioned by professors, we grouped them into five conceptual categories to carry out a comprehensive analysis.

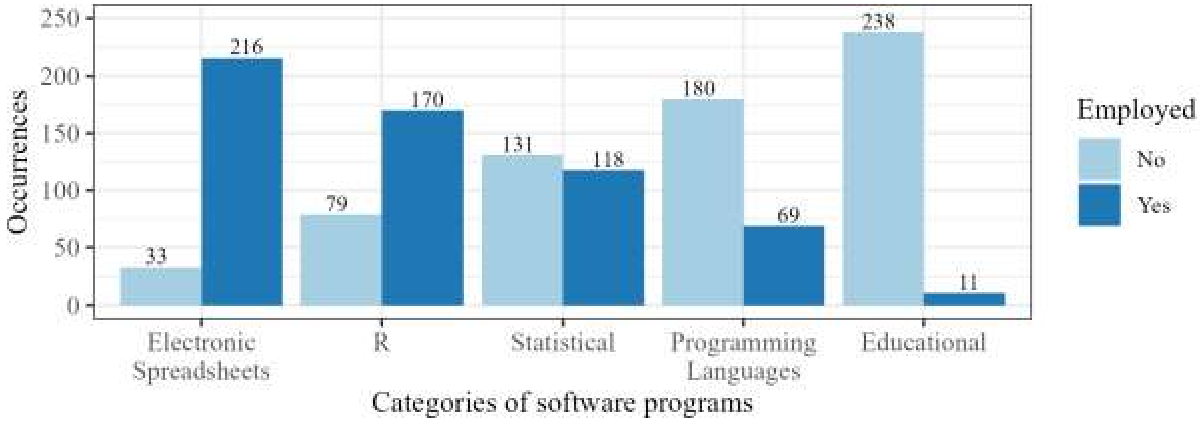
We defined the following categories: Programming Languages, which comprise certain software programs, such as Python, Java and C++, that provide means to develop and execute algorithms; Electronic Spreadsheets, such as Microsoft Excel, LibreOffice Calc and Google Spreadsheets, which are used for organizing data in tables and carry out calculations; Educational Software, such as TinkerPlots, Fathom, CODAP and GeoGebra, which support specific educational activities; Statistical Software, such as SPSS, SAS, Stata, Statistica and JASP, which carry out advanced statistical analyses; and R (here, the R Software), which is highlighted in a single category because of its expressivity and unique features since it is not a mere programming language but also an open-source statistical environment. Specific data on software programs chosen by professors are shown in Table 4 and Figure 4.

Table 4: Categories of software programs

Categories of software programs	Employed		Not employed	
	F_i	%	F_i	%
Electronic Spreadsheets	216	86.7	33	13.3
The R Software	170	68.3	79	31.7
Statistical software	118	47.4	131	52.6
Programming Languages	69	27.7	180	72.3
Educational Software	11	4.4	238	95.6

Source: Research data

Figure 4: Categories of software programs



Source: Research data

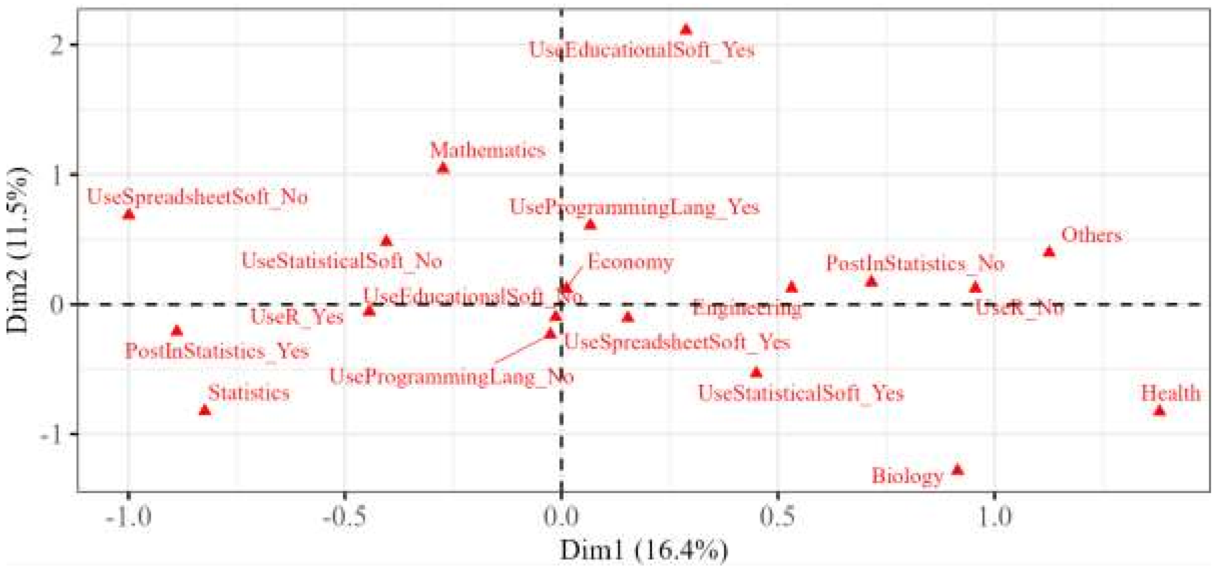
In general, we observed that professors who teach Statistics in Higher Education in Brazil show a decided preference for the use of electronic spreadsheets, such as DICT, since 86.7% of professors stated that they use them. On the other hand, educational software seems to be less accepted since only 4.4% of professors say that they use it.

Emphasis should be given to the use of the R Software, a programming language that aims at statistical computing and graphics. It is used by 68.3% of professors whose choices are aligned with curriculum guidelines issued by the American Statistical Association (American Statistical Association, 2014) and with GAISE's recommendation no. 5 (Carver *et al.*, 2016). Both highlight the importance of using technologies to explore statistical concepts, analyze data efficiently and propose an active approach to improve students' learning significantly.

> Statistics is practiced with computers and usually with specially designed computer software. Students should learn to use a statistical software package if possible. Calculators can provide some limited functionality for smaller datasets, but their use should be supplemented with experience reading typical computer results. Regardless of the tools used, it is important to view the use of technology not just as a way to generate statistical output but as a way to explore conceptual ideas and enhance student learning. [...] Not all technology tools will have all desired features. (Carver *et al.*, 2016, p. 19)

Based on the diversity of professors' undergraduate programs, we asked ourselves how their different fields of knowledge, including post-graduate programs in Statistics, or their absence, could influence their technological choices. To investigate these relations, we carried out the MCA, whose variables were professors' undergraduate programs, post-graduate programs in Statistics (if any) and the use of categories of software programs. Results of the analysis are shown in the correspondence plot in Figure 5.

Figure 5: Correspondence plot



Source: Research data

The MCA did not detect any outlier and the first two dimensions resulting from the analysis explain 27.84% of total inertia of the data set. It means that 27.84% of total variability of individuals (or variables) in the data set is explained by the plane represented by Figure 5. Even though it is a relatively small percentage, it is above the reference value, which is 22.35%, provided by the FactoMineR report and resulting from the simulation of 1,945 data tables of equivalent size based on uniform distribution. Therefore, variability explained by this plane is significant.

The analysis of dimension 1, where individuals on the right of the graph — characterized by a highly positive coordinate on the axis — are opposed to individuals on the left — characterized by a highly negative coordinate on the axis — led to the identification of four groups which are shown in Chart 1. Further information may be found in the FactoMineR report in the repository.

Chart 1: Groups in dimension 1

Group	High frequency*	Low frequency**
1	Post-graduate = No UseEducationalSoft = Yes Undergraduate = Mathematics UseProgrammingLang = Yes UseR = No UseStatisticalSoft = No	Post-graduate = Yes UseEducationalSoft = No Undergraduate = Statistics UseProgrammingLang = No UseR = Yes UseStatisticalSoft = Yes
2	UseR = No Post-graduate = No UseStatisticalSoft = Yes Undergraduate = Others Undergraduate = Health Undergraduate = Engineering Undergraduate = Biology UseSpreadsheetSoft = Yes	UseR = Yes Post-graduate = Yes UseStatisticalSoft = No Undergraduate = Statistics Undergraduate = Mathematics UseSpreadsheetSoft = No
3	Undergraduate = Statistics UseStatisticalSoft = No Post-graduate = Yes UseR = Yes UseSpreadsheetSoft = No	UseStatisticalSoft = Yes Post-graduate = No UseR = No Undergraduate = Mathematics UseSpreadsheetSoft = Yes Undergraduate = Others
4	Undergraduate = Mathematics UseStatisticalSoft = No UseR = Yes UseSpreadsheetSoft = No Post-graduate = Yes	Undergraduate = Statistics UseStatisticalSoft = Yes UseR = No UseSpreadsheetSoft = Yes Post-graduate = No

* Factors are classified from the most common
** Factors are classified from the rarest

Source: Research data

In dimension 2, where individuals in the upper part of the graph — characterized by a highly positive coordinate on the axis — are opposed to individuals in the lower part of the graph — characterized by a highly negative coordinate in the axis —, five groups were identified. They are shown in Chart 2. Further information may be found in the FactoMineR report in the repository.

Chart 2: Groups in dimension 2

Group	High frequency*	Low frequency**
1	Undergraduate = Mathematics UseStatisticalSoft = No UseR = Yes UseSpreadsheetSoft = No Post-graduate = Yes	Undergraduate = Statistics UseStatisticalSoft = Yes UseR = No UseSpreadsheetSoft = Yes Post-graduate = No
2	Post-graduate = No UseEducationalSoft = Yes Undergraduate = Mathematics UseProgrammingLang = Yes	Post-graduate = Yes UseEducationalSoft = No Undergraduate = Statistics UseProgrammingLang = No

	UseR = No UseStatisticalSoft = No	UseR = Yes UseStatisticalSoft = Yes
3	Undergraduate = Statistics UseStatisticalSoft = No Post-graduate = Yes UseR = Yes UseSpreadsheetSoft = No	UseStatisticalSoft = Yes Post-graduate = No UseR = No Undergraduate = Mathematics UseSpreadsheetSoft = Yes Undergraduate = Others
4	UseStatisticalSoft = Yes Undergraduate = Statistics UseProgrammingLang = No UseSpreadsheetSoft = Yes	UseStatisticalSoft = No Undergraduate = Mathematics UseProgrammingLang = Yes UseSpreadsheetSoft = No Undergraduate = Others
5	UseR = No Post-graduate = No UseStatisticalSoft = Yes Undergraduate = Others Undergraduate = Health Undergraduate = Engineering Undergraduate = Biology UseSpreadsheetSoft = Yes	UseR = Yes Post-graduate = Yes UseStatisticalSoft = No Undergraduate = Statistics Undergraduate = Mathematics UseSpreadsheetSoft = No

* Factors are classified from the most common
** Factors are classified from the rarest

Source: Research data

Based on groups described by Charts 1 and 2, we are able to state that participants' undergraduate programs may be considered an important factor in their decision-making processes regarding DICT in their teaching practices. Based on the groups, we identified five main profiles:

- Participants who graduated in Mathematics and did not attend any post-graduate program in Statistics tend to choose educational software programs or programming language in their teaching practices.
- Participants who graduated in Mathematics and attended a post-graduate program in Statistics tend to choose the R software in their teaching practices.
- Participants who graduated in Statistics and attended a post-graduate program in Statistics tend to use statistical software or the R software in their teaching practices.
- Participants who graduated in Statistics and did not attend any post-graduate program in Statistics tend to use the statistical software or electronic spreadsheets in their teaching practices.
- Participants who graduated in any field of knowledge, except Statistics and Mathematics, do not tend to take post-graduate programs in Statistics and tend to use electronic spreadsheets or statistical software in their teaching practices.

To conclude the analysis of results, it should be highlighted that undergraduate programs seem to play a relevant role in technological choices made by professors who teach Statistics in Brazilian Higher Education institutions. This segmentation enables valuable reflection on nuances of integration of different software categories and enriches the discussion about innovative pedagogical strategies in Statistics teaching.

8 Discussion

The approach to statistical literacy proposed by Gal (2002, 2019) emphasizes the importance of developing not only students' cognitive skills but also socioemotional ones to foster critical and ethical comprehension of data management. Such literacy should be a fundamental part of undergraduate programs.

Therefore, Tardif's proposal (2014) for teachers' knowledge is relevant since teaching is a specific and complex practice that requires not only theoretical knowledge but also practical skills. Regarding Statistics teaching in undergraduate programs, we may associate this practice with data analysis related to field of the program, for instance.

In the scenario of technology and Education, the TPACK model (Mishra & Koehler, 2006; Koehler & Mishra, 2009) has emerged as a fundamental guide. The intersection of technological, pedagogical and content knowledge highlights the need for an integrated approach in which educators understand not only statistical concepts but also know how to effectively incorporate technologies into their pedagogical practices.

On the other hand, the discussion about Statistics professors' technological choices proposed by our study points out the relevance of technology in the educational process. Categories of software programs used by them reveal not only individual preferences but also nuances associated with participants' undergraduate programs. In this respect, Shulman (1987) emphasizes the need for pedagogical content knowledge and the capacity to adapt the knowledge to the class context.

Inclusion of the R software as a significant choice highlights the importance of going beyond conventional tools and exploring programming languages committed to Statistics. This approach aligns with both curriculum guidelines issued by the American Statistical Association (2014) and GAISE's recommendations (Carver *et al.*, 2016), besides proposals of the TPACK model, a fact that reinforces that technology is part and parcel of modern pedagogical practices.

Despite all advances, gaps related to critical and intentional use of digital technology in professors' Education processes must be acknowledged. Tardif (2014) has warned us that teaching is a complex practice; in this context, we have identified the need to strengthen professors' Education processes to enable effective integration of technology.

However, the TPACK model emphasizes the intersection of technological, pedagogical and content knowledge as the basis of effective teaching practices with technology. Thus, we propose reflection on strategies of continuous Education that aim at filling gaps in professors' undergraduate programs to prepare them to use digital technology and incorporate it critically and intentionally into their educational practices.

9 Conclusion

This study aimed at investigating practices and technological choices made by professors who teach courses in Statistics in Higher Education and at analyzing the relation between their choices and their previous Education processes. In this study, we carefully examined their preferences for software programs, trends in use and influences of their Education processes. Results show the diversity of approaches and the relevance of digital technology in Statistics Education.

In this scenario, we have asked the following questions: Is there Statistics Education with no digital technology these days? Similarly, is there Statistics Education with no digital literacy these days? These questions not only reflect the intrinsic nature of interaction among

Statistics Education, digital technology and digital literacy but also make us re-examine pedagogical practices constantly to prepare students for the future in which integration of these elements is increasingly indispensable.

Results of this study enable us to conclude that the integrated use of digital technologies in Statistics teaching is desirable and fundamental to promote effective Statistics Education that meets the needs of the contemporaneous world. Data show a variety of approaches and uses of digital technology to prepare students for future challenges. Thus, we highlight that the study enabled us to reach a deeper comprehension of practices and technological choices made by Statistics professors in Higher Education and contribute to continuous reflection and improvement of pedagogical practices in this field.

We acknowledge that our analyses and conclusions are based on participants' answers, a fact that poses some limitations. Even though we tried to join a representative and diverse sample, we should highlight that professors' perceptions and practices may vary widely. We did not try to generalize the professor's profile since we acknowledge the singularity of every educational context. Besides, professors' self-perception may differ from the reality found in class. Even though this study provides valuable insight into Statistics professors' technological choices, these limitations must be considered when results are interpreted.

When we take up the challenge to develop technologically enriched teaching practices, we are not only re-designing the future of Statistics teaching but also collaborating with professors' and students' development so that they may face current challenges in an innovative and effective way. When digital technology is used critically and intentionally, it is a powerful ally in the educational process since it prepares students to face the world which is increasingly oriented by information and technology.

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