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Teaching and learning strategies in a biostatistics course during the pandemic: perceptions of doctoral students[1]

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ABSTRACT

The study analyzes how ten public health PhD students perceive the teaching strategies implemented in a biostatistics course during the COVID-19 pandemic. The teaching strategies implemented within the course through online meetings were reading reports, critical reading of research articles and analysis of real data using specialized and free software. The sources of information were open dialogues with students at the end of the course and written evaluations regarding methodological aspects. Each student assessed the course and analyzed their learning processes and perceptions. In general, students' perceptions of time management, class agenda, reading reports, class-by-class reviews, critical reading, and using statistical software with real data were positive. Results are consistent with previous work about students' perceptions, and these teaching strategies positively transform students' perception of statistics.

KEYWORDS: Students' Perceptions. Teaching and Learning Strategies. Online Education. Statistics Education. COVID-19.

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Estratégias de ensino e aprendizagem em um curso de bioestatística durante a pandemia: percepções de doutorandos

RESUMO

São analisadas as percepções de um grupo de dez doutorandos em Saúde Coletiva sobre estratégias de ensino e aprendizagem em um curso de bioestatística durante a pandemia de Covid-19. As estratégias de ensino implementadas dentro do curso por meio de encontros online foram leitura de relatórios, leitura crítica de artigos de pesquisa e análise de dados reais por meio de softwares especializados e gratuitos. As fontes de informação foram os diálogos abertos com os alunos ao final do curso e as avaliações escritas sobre aspectos metodológicos. Cada aluno avaliou o curso e analisou seus processos e percepções de aprendizagem. No geral, as percepções dos alunos foram positivas em relação à gestão do tempo, agenda das aulas, relatórios de leitura, revisões aula a aula, leitura crítica e uso de software estatístico com dados reais. Os resultados são consistentes com trabalhos anteriores sobre as percepções dos alunos e as estratégias de ensino contribuem para transformar positivamente a percepção que os alunos têm da estatística.

PALAVRAS-CHAVE: Percepções dos Alunos. Estratégias de Ensino e Aprendizagem. Educação Virtual. Ensino Estatístico. Covid-19.

Estrategias de enseñanza y aprendizaje en un curso de bioestadística durante la pandemia: percepciones de estudiantes de doctorado

RESUMEN

Se analizan las percepciones de un grupo de diez estudiantes de doctorado en Salud Pública sobre las estrategias de enseñanza y aprendizaje en un curso de bioestadística durante la pandemia de la Covid-19. Las estrategias didácticas implementadas dentro del curso a través de encuentros en línea fueron la lectura de informes, la lectura crítica de artículos de investigación y el análisis de datos reales utilizando software especializado y libre. Las fuentes de información fueron los diálogos abiertos con los estudiantes al final del curso y las evaluaciones escritas sobre aspectos metodológicos. Cada estudiante hizo una evaluación del curso y analizó sus procesos

de aprendizaje y percepciones. En general, las percepciones de los estudiantes fueron positivas en cuanto a la gestión del tiempo, la agenda de clases, los informes de lectura, las revisiones clase por clase, la lectura crítica y el uso de software estadístico con datos reales. Los resultados son consistentes con trabajos previos sobre las percepciones de los estudiantes y las estrategias didácticas contribuyen a transformar positivamente la percepción que los estudiantes tienen de la estadística.

PALABRAS CLAVE: Percepciones de los Estudiantes. Estrategias de Enseñanza y Aprendizaje. Educación Virtual. Enseñanza Estadística. Covid-19.

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Introduction

The COVID-19 pandemic has impacted different areas of society, affecting its social, industrial, cultural, economic, educational and health structures (CASTRO *et al.*, 2020). Several researchers have reported the effects and consequences of this pandemic on education in general (BAKKER; WAGNER, 2020) and on mathematics education in particular (CASTRO *et al.*, 2020). Students and teachers worldwide were forced to change traditional methods of delivering and administering classes.

Under this scenario, many teachers and students transitioned to new teaching methods supported by diverse technological tools (ENGELBRECHT *et al.*, 2020). To face the impact of the COVID-19 pandemic, the strategy of higher education institutions in Latin America, including Colombia, was to implement virtual classes through free or paid online platforms. Universities could choose implementation strategies depending on their resources (CASTRO *et al.*, 2020).

Due to the contingency experienced in all countries, the importance of mathematics and statistics becomes relevant to analyzing the COVID-19 pandemic, which has had devastating consequences worldwide. Many news

websites use data with graphs and diagrams to communicate the evolution of different epidemiological indicators such as active cases, vaccine availability, etc. In particular, exponential growth models gained relevance as cases spread, and a single carrier could lead to long chains of infection (MATHEMATICS TEACHER TRAINING SCHOLARSHIP, 2020).

Faced with this boom of data and information on the spread of COVID-19, statistics assume a leading role in today's societies, given that data and variability are omnipresent in citizens' daily lives, and the need to interpret quantitative information is present in different contexts (BEN-ZVI; MAKAR, 2015). Statistics provide people with the skills to argue and critically evaluate evidence- and data-based statements in various situations in academic, working and everyday life (BEN-ZVI; GARFIELD, 2004; CARVER *et al.*, 2016)

Therefore, higher education students from non-mathematical disciplines must acquire a basic understanding of statistics and quantitative research (DAVIES, 2021). In the international context, the role of statistics in general training is recognized, in particular, for future professionals in the medical and health areas (SAHAI; OJEDA, 1999). Training in statistics is fundamental in the health sciences since it allows the development of skills related to the critical analysis of results, the design of quantitative studies —in which randomness and uncertainty are present—, the reflection regarding the conclusions obtained and the decision-making in the healthcare context (OCAÑA-RIOLA, 2016).

Statistics at the university level is seen as a difficult or tedious subject, especially by students from disciplines other than science, technology, engineering, and mathematics (STEM) (GUNDLACH *et al.*, 2015). This is the case of students in the fields of health and social sciences, who are generally motivated to study their professional field but usually have no interest or motivation in learning to analyze data using statistical procedures (SAHAI; OJEDA, 1999).

Among the challenges of statistical education is the use of teaching strategies in the classroom to promote learning goals, such as statistical reasoning of students at different levels of education, particularly of graduate students in health sciences (BARGAGLIOTTI *et al.*, 2020; BEN-ZVI; MAKAR; GARFIELD, 2018). Statistical reasoning in the context of health sciences allows the understanding and interpretation of risks, opportunities, and results of diagnostic tests in medical studies (GARFIELD, 2002).

Although there are different conceptualizations of statistical reasoning in the literature, in this manuscript, we consider it a set of mental and analytical processes that the professional or future health professional must carry out to identify, understand, analyze, and interpret the natural history of a disease and the behavior of health events. This set of skills includes data analysis: recognizing sociodemographic, clinical, and epidemiological variables, identifying outcome variables and factors associated with them, as well as putting into practice statistics based on inferences, univariate, bivariate, or multivariate analysis to assess the evidence and propose appropriate statistical procedures and methods (DELMAS, 2004; FIORAVANTI; GRECA DUFRANC; MENESES VILLAGRA, 2019; GARFIELD; BEN-ZVI; CHANCE; ROSETH *et al.*, 2008; LOVETT, 2001; OCAÑA-RIOLA, 2016; SHAUGHNESSY, 2007).

Recent changes in statistical education research propose a teaching of statistics that transcends formulas, procedures, and computational skills, promoting teaching focused on students' learning and statistical reasoning aimed at understanding, analyzing, and interpreting data and results in the context of the future professionals (BATANERO, 2019; BEN-ZVI; GARFIELD, 2004; CARVER *et al.*, 2016). Some recommendations established by the Guidelines for Assessment and Instruction in Statistics Education (GAISE) are: integrate real data in context, promote active learning, use technology to explore concepts, analyze data, and use tools to improve and assess learning. Regarding the evaluation suggested by researchers to foster

statistical reasoning, the literature reports the use of tests, generally multiple choice, as well as evaluation based on projects, reading reports, and critical reading of articles (CARVER *et al.*, 2016; GARFIELD; BEN-ZVI; CHANCE; MEDINA *et al.*, 2008).

Apart from the importance of evaluating cognitive aspects such as statistical reasoning, the literature also reports the need to assess students' affective aspects that influence the cognitive domain (GARFIELD; BEN-ZVI; CHANCE; ROSETH *et al.*, 2008). These non-cognitive factors include, but are not limited to, attitudes and beliefs, self-efficacy, and general perceptions of students taking statistics courses (BEN-ZVI; MAKAR; GARFIELD, 2018). Several researchers in statistics education have explored how these non-cognitive factors are related to statistics learning in university students (ZIEFFLER *et al.*, 2008).

This research assesses students' perceptions of the course methodology and the implemented teaching strategies. Students' perceptions are a primary source of information that can provide a continuous view of several critical dimensions of teaching: classroom performance, counseling, and informal and formal contact with students outside of class (GRAVESTOCK; GREGOR-GREENLEAF, 2008).

"Many instructors are aware that statistics does not always have the best reputation among students and those perceptions affect their overall experience" (LAWTON; TAYLOR, 2020, p. 46). Thus, knowledge about non-cognitive factors, such as students' perceptions of statistics teaching strategies, is important since it allows teachers to design their courses better to promote statistics learning (ZIEFFLER *et al.*, 2008).

Literature review

Research on mathematics education about learning and problem solving has traditionally focused on cognitive factors, ignoring affective factors (CHEN; LEUNG; SHE, 2023). According to Leder and Grootenboer (2005), the affective domain, which includes beliefs, values, attitudes,

emotions, and feelings, is of great importance because they could help improve student learning of mathematics and related fields like statistics.

Countless mathematics and statistics education researchers have reflected on students' perceptions and views of teaching strategies and classroom environments with students from different educational levels. For example, Koaparan (2015) investigated teachers' views about difficulties in learning and teaching statistics at a Turkish university. He conducted semi-interviews with ten middle-school mathematics teachers, analyzed their views about the subject of statistics and found that 1) teachers perceived as positive that statistics were taught gradually in every grade, but 2) teachers experienced that students had difficulties in various topics regarding statistics teaching and learning: context, sample, data representation, probability, among others. A similar study by the same author reflected on prospective mathematics teachers' views about teaching materials developed by them (KOPARAN, 2017).

Regarding students' perceptions, Perales *et al.* (2023) and Chiphambo, Mtsi and Mashologu (2020) explored students' views about innovative teaching with high school and university students, respectively. The former study focused on understanding students' perceptions within a computer-supported collaborative learning environment in an algebraic reasoning class. This study found that, in general, students perceived positively the proposed environment because they valued it as user-friendly and considered it to support their algebraical reasoning, providing multiple ways to learn. They also valued as positive the social interactions and the activities created (PERALES et al., 2023).

A similar study explored students' perceptions about the teaching strategies in a mathematics course at a South African university (CHIPHAMBO; MTSI; MASHOLOGU, 2020). The study has two main findings: 1) Students agreed that mathematics teachers should encourage in them attributes like empathy, caring, equity, and commitment, and 2) To improve the learning of first-year mathematics, it is necessary to

articulate several factors, such as having an stable curriculum, the availability of teaching and learning resources, to have experienced teachers who can integrate technology into teaching and learning, the use of proper mathematical language when teaching, and the active engagement of the students.

Also, in statistics education research, some previous studies have reported the usefulness of implementing different strategies for teaching statistics in virtual environments and students' positive perceptions of these strategies. For example, Davies (2021) says that all the interviewed students expressed a liking for the proposed course and valued the possibility of sharing online information with their classmates. The research results are related to the redesign of the module, the teaching strategies implemented in class, the dialogue with students, the good group communication and, in general, a pleasant classroom environment. Furthermore, the fact that the doctoral students already knew each other and were part of the same doctoral cohort could induce a 'cohort effect', also observed in other graduate programs (DE LANGE; PILLAY; CHIKOKO, 2011).

In another study, Lawton and Taylor (2020) investigated students' perceptions of their engagement in an introductory statistics course. For this, students voluntarily answered two instruments: a daily survey at the end of each class and one at the end of the semester. The questions asked about the level of commitment the students considered they had in each class and the activities they thought were the most interesting. The researchers found that the students showed little interest in reading articles and working on projects. In contrast, 70% of the students expressed a positive perception of classroom activities such as software simulations and working independently through problems with teacher support (LAWTON; TAYLOR, 2020).

Although previous studies have given relevant contributions to research on student perceptions, more research is required to analyze perceptions in other populations of students generally not considered,

such as graduate students in health sciences. Graduate students have different characteristics from high school and college students, such as age, academic and professional background, and research experience (ZHANG *et al.*, 2012). In addition, in the case of postgraduate students in the health areas, they usually have professional experience in various fields such as public health and epidemiology. Despite the differences, this population has been insufficiently studied in statistical education research (ANDRADE; FERNÁNDEZ; ÁLVAREZ, 2017; SANTABÁRBARA; LÓPEZ-ANTÓN, 2019).

Therefore, there is not much research on health graduate students' perceptions of teaching strategies. Research on students' perceptions of their learning processes can offer opportunities for training and research communities. These communities can recognize the resources, methods, and tools used and the benefits and limitations they offer in the potential learning of students; therefore, they provide input for the curricular designs of the courses. This paper aims to answer the following research question: How are the perceptions of doctoral students regarding teaching strategies implemented in a course on Biostatistics of the doctorate in Public Health at a public university in Colombia?

Method

Course and participants' description

Given the educational crises caused by the COVID-19 pandemic, universities and postgraduate education programs offered statistics courses virtually, using a variety of formats, including synchronous encounters supported by virtual tools. The Biostatistics course in question was complemented by asynchronous activities in virtual learning environments, in particular, using the Moodle platform. Resources were created, and materials were hosted, including directed readings of scientific texts and

articles, class notes, assessments, videos, and discussion forums (GUNDLACH *et al.*, 2015).

This case study was conducted in a Public Health faculty of a public university in Colombia. Faced with the pandemic, the Postgraduate Committee offered in-person training courses supported by online tools, using Moodle as the main platform for the course organization, and Zoom for synchronous encounters. The course is part of a doctoral program in public health. The program is face-to-face with full-time dedication and a duration of eight academic semesters of 16 weeks each.

This doctoral program is an advanced education program in research, oriented to generating knowledge in public health and searching for solutions to health problems. The program promotes a permanent attitude of reflection and constructive criticism towards science and public health policies. It has approximately ten students with a master's degree per cohort. Students' education is framed in the areas of health and social and human sciences. Students are admitted to the program after approving an evaluation process that consists of two steps: evaluation of the curriculum vitae, in which academic, work, and research experience in the health sciences is appraised, and evaluation of the proposed research project in one of the research lines of the doctorate.

Within the curriculum of the doctoral program, statistics education consists of two biostatistics courses during the second and third semesters. The Biostatistics-II course aims to help students understand and properly apply statistical techniques related to parametric and non-parametric inference, with generalization of results to one or more populations, based on extracted samples, to apply the results in public health. Biostatistics-II is a course of the basic training component of the doctoral program in public health, with 48 hours of in-person teaching and 105 hours of extra-class work. During the COVID-19 pandemic, the course was offered in the second semester of 2020 through synchronous meetings of four hours using the Zoom

platform. The resources and materials from Moodle supported both synchronous classes and asynchronous work.

The contents addressed in these modules were grouped according to the parametric and non-parametric methods. Regarding the first one, the course included a) Normality tests, b) Hypothesis testing, c) Confidence intervals and d) Analysis of variance. Concerning non-parametric methods, a) Generalities of non-parametric tests, b) Independence tests (Chi-square test of independence, Fisher's exact test) and c) Non-parametric common tests in epidemiological research (runs, Chi-square, Wilcoxon, U-Mann-Whitney, Kruskal Wallis, Spearman correlation).

These contents were taught in 12 sessions of four hours each. Each session was supported by virtual tools. The general structure of each class was as follows: presentation of the class agenda, review and discussion of the reading reports, explanation of the topic, practice with real data using R Studio statistical software, joint reading of an article, discussion of learning activities and other concerns.

Teaching strategies implemented during the course

The Biostatistics course addressed the contents of inferential statistics with parametric and non-parametric techniques, which constitute an essential tool for empirical-analytical research in different disciplines, specifically in Public Health. It is usual that, while developing their doctoral thesis and reading articles, students must understand, apply and interpret results derived from inferential statistical analysis that help them support decision-making and correct interpretation of findings reported in previous studies. Several teaching strategies were implemented, such as reading tasks before, during, and after the session, reading reports diagrams, critical reading of articles, and analysis of real data secondary-source databases using specialized and free software. These strategies are described later.

Before attending each synchronous meeting, we assigned readings to the students, for example, the principles for conducting a one-way ANOVA. This allowed them to acquire the basic knowledge of the subject to be dealt with before the class, identify the application scenarios of the different statistical procedures, and have arguments to contribute to the discussion during the synchronous meetings. The development of the classes focused on analyzing and discussing situations and scientific papers. Following Jones and Palmer (2020), we created a class focused on discursive events based on previous work, making use of learning conversations between students and teachers, facilitating interaction, collaboration, and active participation, thus achieving reflection and discussion about the learning process of each student (WISKER *et al.*, 2003).

In class sessions, statistical analyses were performed with real data, as suggested by Carver *et al.* (2016). In this sense:

> Using real data in context is crucial in teaching and learning statistics, both to give students experience with analyzing genuine data … using real data sets of interest to students is a good way to engage students in thinking about the data and relevant statistical concepts. (CARVER *et al.*, 2016, p. 17)

In the particular case of the described course, real data from the public health context was used, allowing candidates to articulate the knowledge of the context with the performed statistical analyses (PFANNKUCH, 2011).

Additionally, a strategy used in class sessions was "on-screen demonstration", following the principle of showing instead of telling (ZHOU, 2018). Students shared their R Studio screen to show the structure of the code and the routines they were building, allowing all the participants to observe the execution of the statistical analyses. During the classes, communication and interaction took place verbally by activating the microphone or through chat messages from the room.

Students were encouraged to actively participate, not only through learning conversations but by running the statistical tests on their own devices, writing their own documents, and presenting results to other attendees. Class sessions were recorded and made available to students for review purposes and as input for independent study.

A session of the Biostatistics-II course is described below. Each session lasted four hours, with a 10-minute break every hour and a 20-minute break after the first two hours. The agenda of the sessions was structured in five moments:

1. Reading reports: before class, students were assigned a reading on a topic to become familiar with the key points. This material was referenced in the course program and available on the Moodle platform. The students made a brief presentation in PowerPoint in pairs, in which they presented their reading report with a summary and outline of the topic to be discussed. Both teachers and other students asked questions and made comments about the report.
2. Theory: by means of a theoretical scheme made in OneNote and writing technological resources, teachers presented the type of statistical analysis, the variables to consider, the assumptions to take into account, and the application of such analysis in public health situations.
3. Real case application using the free software R Studio: to promote and develop students' statistical reasoning in different stages of the statistical research, the recommendations of the GAISE guide were followed: to integrate real data with context and purpose and to use technology to explore concepts and analyze data (BARGAGLIOTTI *et al.*, 2020; CARVER *et al.*, 2016). To do this, we promoted the use of real data from previous research in the context of public health, encouraging result analysis and replicating the parametric and non-parametric techniques implemented in the research. For example, an investigation on burnout syndrome and job satisfaction of a population of university professors was analyzed and discussed with the students (ROJAS;

ZAPATA; GRISALES, 2009). Reading the article, the students understood and interpreted data within the topic of interest, burnout, for this case. Subsequently, the students carried out an analysis plan to identify the variables to be used and established the appropriate statistical methods according to the nature of the variables, the fulfillment of assumptions and the hypotheses to be tested. Finally, the students executed proper statistical techniques in R, interpreted the results in context, and presented their conclusions in Word.

4. Critical reading of research articles: in class, 15 to 30 minutes were set aside to read some sections of a research article related to the topic. The students began by first reading the summary, the introduction and the conclusions to get familiarized with the research topic. Each group was then given approximately 20-30 minutes to read and discuss the methods and results of the publication. In the results section, the students had to identify the ones in which the parametric techniques that were being studied were applied. Subsequently, 20 minutes were dedicated to a critical reading of the conclusions, discussing whether they were adequate and consistent with the research question and the applied methods. Finally, there was a space for discussion with all the groups to socialize the reading process and clarify arising questions.

As an example of a critical reading task, 10 days before a presentation, a reading of a research article related to the suicide attempt in a Colombian city in 2017 was assigned. The objective was to analyze statistical reasoning on different sections of the publication. The students worked in pairs and answered questions about the parametric and non-parametric univariate statistical analysis of one variable and about the bivariate analysis between two of the variables of interest. In each case, the students read and interpreted the results of the article in the context of the data and raised the appropriate hypotheses according to the

statistical technique applied. An example of this specific critical reading task is shown in the annex 1.

At the end of each class session, we asked questions to summarize and provide feedback on concepts and theories studied during the session. Students were invited to imagine possible scenarios where they could apply statistics in their ongoing research or in research projects in the frame of their doctoral training. They were also invited to reflect on the achieved learning and on the difficulties perceived during the development of the class, in order to improve future meetings.

Research method

Ten students followed the course, seven men and three women, aged between 30 and 40 years. All enrolled students attended all class sessions, participated actively, and fulfilled the commitments established in the course program, 100% of the participants approved the course.

The research method used was qualitative, based on a pragmatic paradigm and an interpretive epistemology, where it is assumed that research always occurs in social, historical, and political contexts. Thus, the knowledge obtained during the course and the statistical reasoning gained by the students is supported by their perceptions and responses (CRESWELL, 2014; CROTTY, 1998). The sample was selected for convenience, given the characteristics of the course and the small number of registered doctoral students. All ten students participated in the study.

The research design corresponded to a case study, where we in-depth analyzed ten public health PhD students' perceptions of the teaching strategies used in the Biostatistics-II course (GILLHAM, 2000). A valuable method to examine those perceptions was their assessments of the course and the teacher. This method constitutes a source of relevant information when integrated into the policies of higher education institutions (GUNDLACH *et al.*, 2015). However, students' perceptions do not have to be limited to course

assessment since there are other sources of information such as interviews, questionnaires with former students and face-to-face discussions (GRAVESTOCK; GREGOR-GREENLEAF, 2008).

In this research, open dialogues with students at the end of the course were a source of information, as well as written evaluations that some of them carried out regarding methodological aspects. Open-ended questions call for unplanned responses, allowing the participants to respond in their own words (CHIPHAMBO; MTSI; MASHOLOGU, 2020; POPPING, 2015). The open dialogues were held with ten students at the end of the course and were recorded by videoconference with all the students' consent.

Each student assessed the course and analyzed their learning processes and perceptions. The dialogues were held by open-ended:

1. How was your training and learning experience in the Biostatistics-II course?
2. How do you value the methodology (development of virtual sessions) followed throughout the course?
3. How do you assess the evaluation strategies that were developed in the course? What is your point of view towards each one (positive and negative aspects) ?
4. What are the general positive and negative aspects of the course?
5. What are the positive and negative aspects of your performance during the course?

After the dialogue, students were invited to voluntarily make a written assessment of the methodology and teaching strategies of the course. In written format, this feedback was requested by mail and by the Moodle platform. The following questions were asked to guide the student's assessment of their perceptions regarding teaching and learning strategies to promote statistical reasoning:

1. Do you consider that working with the software R Studio contributes to your training in biostatistics (mention positive and negative aspects)?
2. Choose the evaluation activity you liked the most and explain why.
3. Describe what you understand by statistical reasoning in the health field.
4. Do you consider that the design and development of the course promotes statistical reasoning in health professionals? (Explain).

To ensure internal validity, the following strategies were employed (CRESWELL, 2014; MILES; HUBERMAN; SALDAÑA, 2014):

1. Triangulation:
    a. Of data: data collection involved several sources of data, including open dialogues and written student assessments about the course and teaching strategies implemented.
    b. Of theories: in this research, multiple frameworks were used among statistics education research and education, like social constructivism, pragmatic (learning by doing) and situated learning (in the context of health sciences).
2. Clarification of researchers' bias: the researcher's role is clarified. In this case, two researchers were teachers during the course and participated in data collection and coding. They have similar experience teaching statistics to postgraduate health sciences students and both align with social constructivism and Guidelines for Assessment and Instruction in Statistics Education (GAISE) (CARVER et al., 2016). They agreed in the themes and subthemes found. All authors contributed to data analysis, and conclusions and the third author participated as a peer examinator.

To guarantee external validation, rich and detailed descriptions of results were provided. To ensure reliability of the study researchers, provided: a detailed description of the methodology employed, accounting for the focus of the study, the researchers' role, and data collection of the

participants and their context. Also, the use of multiple data collection sources strengthens the reliability of the research. Finally, evidence of credibility was achieved through the maximum variation sampling strategy, which involved purposeful sampling (convenience sample).

Data analysis

The analysis of how a group of public health PhD students perceived the development of the Biostatistics-II course followed these stages (CRESWELL, 2014):

1. Data organization and preparation: transcription of the open dialogues, organization of the video recordings, and systematization of the written evaluations.
2. Reading of all data: the videotapes of the interviews were reviewed, and the researchers took notes of the most relevant aspects regarding the students' perceptions of the course and the teaching strategies. The written evaluations were also read.
3. Data coding: each participation of students in the dialogues is defined as an analysis unit, and each transcription of each line of the written assessments. Then, an inductive coding approach (MILES; HUBERMAN; SALDAÑA, 2014; SKJOTT LINNEBERG; KORSGAARD, 2019) was used to identify three main themes, considering that they reflected the multiple perspectives of the future PhDs. In the first codification cycle, two authors sought to account for the students' evaluations of the strategies, the perceived opportunities for learning, the relevance for the remote course, and the resources used. After this coding, the research team met to discuss the first findings, considering the divergences until reaching a consensus. A second coding was carried out, looking for data that reflected the language of emerging information from the data, and there is no hierarchy between themes.

Additionally, a series of sub-themes were defined within each theme to deepen the data analysis.

4. Analysis of the themes: a detailed discussion of each theme and sub-theme was carried out, relying in each case on quotes from transcripts of the open interviews and sections of the written evaluations. We used pseudonyms in all the citations to guarantee the anonymity of the participants.
5. Interpretation of theme meanings: the researchers proceeded to interpret the findings, comparing them with what was reported in the literature about students' perceptions in similar situations. While discussing the literature, the researchers compared the obtained results with previous studies to confirm the effectiveness of the statistics teaching strategies implemented in the Biostatistics-II course.

Results

As a result of the analysis of the dialogues with the students and the written assessments of four of them, three themes emerged: 1) perceptions on the teaching of statistics in the context of the COVID-19 pandemic using virtual tools 2) perceptions about the teaching strategies of the course and 3) social and situated aspects of learning. By limits of space, in this study, we report and summarize the results for the first two themes in table 1, with their corresponding sub-themes.

TABLE 01. Themes and sub-themes emerging from students' dialogues and written assessments feedback.

Theme	Perceptions on the teaching of statistics in the COVID-19 pandemic context using virtual tools	Perceptions about the teaching strategies of the course
Sub-themes	Liking towards the statistical class Time management and course organization Synchronous online learning	Critical reading of articles Reading reports. Sessions with the software R

Theme 1: perceptions on the teaching of statistics in the COVID-19 pandemic context when using virtual tools.

In general, we found that the students valued as positive aspects (i) the liking that they developed about the classes, (ii) the thematic organization and the timing of the class sessions, and (iii) the theoretical explanations,

Some students declared that, although at the beginning of the course they were reluctant to follow it and felt dislike and fear towards the course due to their previous experiences, these were overcome thanks to the methodology implemented. The students expressed their fears and doubts when, from the doctoral committee, they were invited to follow the course with the help of virtual tools. In this regard, Daniel pointed out: "*I had many doubts that, virtually, one could learn; rather, I was saying: one cannot learn statistics virtually, that is impossible! Suddenly, one does not think about the transformation towards virtuality [Daniel, open dialogue, March 2020*". In the same way, Cristina, another doctoral student, stated that:

> *In the virtual process, there were fears about the understanding that could be achieved, but when receiving the classes and carrying out exercises of knowledge appropriation, such as reading reports, practice with the software and critical reading of articles, the learning objectives could be met satisfactorily [written assessment, March 2020].*

Other students highlighted the role of synchronous online learning, for example Santiago indicated:

> *The online education experience has allowed us to understand that learning transcends space-time barriers, making possible real and concrete learning experiences when one has access to the means and resources for it, a possible task in the Bio-II seminar [written assessment, March 20].*

The preceding opinions show some students' previous perceptions regarding learning statistics in virtual environments and highlight the potential that virtuality can have in statistics courses when different teaching strategies are implemented.

Furthermore, some students positively valued not only the course but their own learning process, such as Cristina, when she affirmed, "*I think you teachers have a very interesting didactic. I had already seen many of the concepts in other training processes, but now I feel I had a deeper learning*" [open dialogue, March 2020].

Several students agreed to focus on the importance of different methods and resources in online learning, as Andrea expressed:

> *The teachers implemented excellent methodologies for the development of the classes. I even think that I learned much more in this online format than in other physical face-to-face experiences; there was a range of tools such as the boards, the videos, and the suggested study material that were key elements in the development of the course [written assessment, March 2020].*

The previous statements are examples of students' perceptions who, at the beginning of the course, had some fears about the course and the use of the software. However, the teaching strategies implemented in the course helped transform negative perceptions and fears, and, at the end of it,

students expressed a liking for statistics as a virtual course. Also, the class sessions atmosphere was valued positively. In this regard, Sebastian said, *"The class environment was very pleasant, and one loses the fear of asking questions" [open dialogue, March 2020].*

In addition, the adequate management of time and resources was another positive aspect; for example, when Isabel highlighted that *"I really liked how the teachers managed the timing and the breaks. The dynamics of the class made learning much easier"* [open dialogue, March 2020] or Santiago, when he stated that,

> *An element of great value with respect to the methodology is, without a doubt, the arrangement of the class through blocks or moments (input - conceptual - practice and review of the text) and the arrangement of the evaluative aspects of the module (reading reports, workshops, evaluation) [written assessment, March 2020].*

What students told us orally and in writing reveals their perceptions of the content and organization of the Biostatistics-II course and its development when COVID-19 spread worldwide. Future PhDs in public health changed their perceptions of the teaching and learning of biostatistics supported by virtual tools. They positively valued time management, breaks, the atmosphere of dialogue in each session, the followed agenda, and the strategies implemented at each moment of the class.

Theme 2: Perceptions of the teaching strategies of the course.

In this theme**,** students positively perceived the teaching strategies used in the course and expressed obtaining a better understanding of the topics studied. In general, they value the following strategies**:** (i) the reading reports and their class-by-class review, (ii) critical reading of articles that

supported the implementation of the statistical topic covered in class, and (iii) the practical sessions with real data using the statistical software R.

For example, Isabel highlighted the usefulness of statistics in their context when she said, *"It was a very enriching exercise to see the usefulness of statistics in public health research" [written assessment, March 2020].* For their part, other students positively perceived some strategies implemented in the course, especially reading reports, critical reading of articles and software practices. So, for example, Andrea commented, *"I emphasize the importance of reading reports and the socialization by groups, which, although they imply hard work, allow learning to be strengthened" [open dialogue, March 2020].*

Similarly, Daniel, referring to the report reading, assessed them as a valuable product and added: *"Reading reports, more than an evaluative activity, are a product of the course that is useful for us, ... it is an activity of synthesis of all the relevant aspects: the contents, the articles, the class practices in R" [written assessment, March 2020].* Likewise, Santiago agreed that reading reports was a good strategy because it was carried out by peers or working groups. In this way, students considered that the evaluation fulfills its main objective of being part of the very formative process.

Critical reading of articles was another strategy well valued by the students in terms of its contribution to their formative process. For example, Andrea agreed to highlight its importance throughout the class sessions when she affirmed that *"actually, I liked all the evaluative activities and found them interesting, but the most challenging and the one from which I learned a lot was the article-type report of data analyzed with the program R" [open dialogue, March 2020]* and Oscar considered that

> *Critical reading of articles allowed me to see the knowledge applied from the researcher's perspective, look at my strengths and weaknesses when presenting the articles. That gives me useful*

> *experience in case I had to write one… With these article reviews, articles are no longer read in a naive and totalitarian way but, on the contrary, in a critical way, understanding what they express and what the researchers lacked to express [open dialogue, March 2020].*

On the other hand, the practices with the R software were positively valued by the students. A common aspect among some students was the aversion they felt at the beginning of the course towards handling the software, as when Cristina pointed out, *"Suddenly one has an aversion to these issues and thinks: no, the statistician will help me later to obtain the results" [written assessment, March 2020].*

In this regard, some students highlighted how the course allowed them to overcome this negative perception, for example, when Andrea stated that thanks to the teaching methodology of the statistical software *R, "I was able to reconcile myself with this tool, since I had an aversion to it and discovered that it provides innumerable benefits in statistical training for the analysis of different databases" [open dialogue, March 2020]* and Oscar expressed that *"R Studio is publicly accessible and free. This allows us to have at hand a program to help us analyze and interpret data… this course helped me reduce the fear I felt with using the software" [open dialogue, March 2020].*

Thus, both students agreed that the course helped them to overcome the negative perception they felt when using the software. The practices with the program R, together with the on-screen demonstration, showed students the advantages of using free software in terms of data analysis in the context of their professional field, public health, in this case.

Other students who also worked as biostatistics professors said that their confidence improved with the use of the software. For example, Sebastian stated, *"Now I can say that I do dare to dictate biostatistics with the support of the software R" [open dialogue, March 2020].*

In addition, the practices with the software were also valued as a strategy that allowed to carry out different processes that are part of statistical reasoning. In this regard, Santiago stated: *"Learning to use R has been one of the great lessons in biostatistics for me. Undoubtedly, carrying out real practices during the course is an element of great value in learning" [written assessment, March 2020].*

Students reported a positive perception of reading reports, the critical reading of articles, and the practices with the software R. They assumed a more active position regarding their own learning and the investigation of publications in the context of health. In addition, some strategies, such as reading reports, when proposed as synthesis activities of the relevant aspects of the classes, were articulated with the practical guidelines and recommendations provided in the literature regarding alternative forms of evaluation that promote the development of reasoning of students who take a statistics course at the university level (CARVER *et al.*, 2016; GARFIELD; BEN-ZVI; CHANCE; MEDINA *et al.*, 2008).

Discussion and conclusions

Theme 1

Davies (2021) suggests that the approach of conducting conversations with students can be useful to reduce any fear that candidates experience about statistics and encourages them to contribute and ask questions. Finding ways to support, nurture, and maintain high expectations in a virtual environment is a challenge that requires individualizing the teaching process, which is feasible in small groups (MADDEN, 2019).

The fact that students posed questions to each other and could confront their ideas and conceptions about different statistical concepts and methods would contribute to the learning of statistics since, according to Garfield and Ben-Zvi :

> Students seem to learn better when activities are structured to help students evaluate the difference between their own beliefs about chance events and actual empirical results. If students are first asked to make guesses or predictions about data and random events, they are more likely to care about and process the actual results (GARFIELD; BEN-ZVI, 2007, p. 388).

Theme 2

Students' perception of the reading report strategy was positive since they saw it as an important synthesis exercise that required them to read before, during, and after class. It is a strategy that requires time and offers the possibility of collaboratively work with peers. Reading reports is a form of formative assessment that allows teachers to follow and improve student learning through feedback about their learning process. This type of report helped students strengthen their knowledge of statistical concepts and improve their communication skills (CARVER *et al.*, 2016). Asking students to use their own words to explain their understanding of various statistical concepts and methods is an alternative form of assessment that requires developing communication and synthesis skills (GARFIELD; BEN-ZVI; CHANCE; ROSETH *et al.*, 2008).

The previous approaches align with what has been reported in the literature on the benefits of critical reading of articles. Since one of the goals of the GAISE is that students should become critical consumers of statistically based results reported in the media, recognizing when the reported results are logical consequences of the study and its analysis, the critical reading of articles is considered an evaluation strategy that fosters in students the ability to analyze and value the information of the results reported in research (CARVER *et al.*, 2016; GARFIELD; BEN-ZVI; CHANCE; MEDINA *et al.*, 2008).

Critical reading of articles is a strategy that promotes students' statistical reasoning skills related to the interpretation of research results, argumentation based on quantitative evidence, and communication of results in the context of the data (CARVER *et al.*, 2016; GARFIELD; BEN-ZVI; CHANCE; MEDINA *et al.*, 2008). This strategy represents an alternative evaluation method since:

> Most students will eventually find themselves consumers of statistical information rather than producers. Therefore, if the course goal is developing students' ability to process and analyze quantitative information in the media, assignments can be designed to help develop these skills... Possible examples are providing students with a journal article and asking them to evaluate the use of statistics and the conclusions drawn. (GARFIELD; BEN-ZVI; CHANCE; ROSETH *et al.*, 2008, p. 80).

Discussion

This study presents how PhD students perceive the biostatistics course teaching strategies used at a postgraduate program in health sciences within the framework of the COVID-19 pandemic. The results of this case study indicate that the students evaluated the course format –which uses virtual tools– positively; i.e., they perceived it satisfactorily. Some students stated that they had learned more compared to previous training experiences with face-to-face teaching, which challenges other studies that report little satisfaction on the part of students with teaching through virtual environments due, in part, to the fact that the willingness towards this type of education has not been optimal and to some difficulties of communication and access to education technology, among others (AL SOUB; ALSARAYREH; AMARIN, 2021; BAWANEH, 2021).

The results of this investigation are consistent with the ones reported by Davies (2021) in a similar study with students of a doctoral seminar of a module on quantitative methods of investigation and statistics. In both studies, students' perceptions of the course methodology and teaching strategies in virtual environments were valued positively, which allows us to suggest a possibly positive effect of student-centered strategies on students' perceptions.

The distribution and organization of the course contents through modules allowed the course to be taught in a sequential and organized way as proposed by Schuessler (2017), addressing first the parametric techniques and then the non-parametric ones, which allowed the students to have a better understanding of the different statistical techniques implemented. Other key aspects regarding the course methodology were the frequency of class sessions, the class time management, and the allocation of enough time to cover all the necessary topics. In addition, given the demand for extra-class time required by this type of course, the students appreciated the possibility of receiving extra-class advice offered by the course teachers, especially to work with the problems proposed in evaluations. The above facts are consistent with what Budé *et al.* (2009) reported: the students' subjective perceptions of the course, the professors and the discussions in counseling and other meetings were more positive when students were given a guiding support.

Another strategy used by the students was the on-screen demonstration of the analyses carried out with the software, thus facilitating the support provided to students when receiving real-time feedback. In this sense, students perceived that they benefit when they can show what they can do, interact in various ways, and have options regarding how they learn (GUNDLACH *et al.*, 2015). Following Zhou (2018), the on-screen demonstration strategy improves understanding and promotes active participation, in which one learns by doing while analyzing data from your professional context.

On the other hand, at the beginning of the course, some students were afraid of statistics, especially regarding the software. Due to previous experiences, they had negative perceptions of statistics classes, where teachers privileged formulas and traditional teaching. The approach proposed by the teachers to foster dialogue with the students at the beginning, during, and at the end of the class sessions allowed these perceptions to be transformed and encouraged the students to ask questions during the process. These findings are similar to those reported in the study by Davies (2021), in which the students expressed overcoming their fears and changing their negative perceptions while learning biostatistics.

Together, this research describes and analyzes the perceptions of graduate students of a Biostatistics course in the context of the pandemic and making use of some teaching strategies designed to promote statistical reasoning. Knowing the perceptions of students who take statistics courses is important because these perceptions influence their learning of the subject. In addition, they constitute a primary source of information that is relevant to teachers to improve their course design and promote students' learning (GRAVESTOCK; GREGOR-GREENLEAF, 2008). "More specifically, a student who sees statistics as a barrier to a chosen vocational path might not value being asked to strive for depth in understanding statistical notions" (ZIEFFLER *et al.*, 2008, p. 9).

The present study shows that it is possible to face some educational challenges in terms of students' perceptions of statistics teaching in the context of the COVID-19 pandemic. For this, it is essential to implement methodologies focused on student learning, as stated in the recommendations of the GAISE guide. Thus, as suggested by Zieffler *et al.* (2008): "It is important that statistics teachers remain aware that students come to statistics courses with great variation in expectations and perceptions of what statistics is about" (ZIEFFLER *et al.*, 2008, p. 10). Then, it is essential to help students experience the practice of statistics, which, in turn, helps them understand its power and usefulness. However, for a better understanding of the teaching-learning process of the subject, new studies are required in which strategies suggested in the literature

are implemented, such as critical reading of articles, working with real data in context, and working through projects in which students get involved and can apply different stages of the research cycle (CARVER *et al.*, 2016; GARFIELD; BEN-ZVI; CHANCE; MEDINA *et al.*, 2008).

Therefore, reading reports, critical reading of articles, and the use of technology as strategies implemented in the statistics course contribute to positively transforming students' perceptions of biostatistics, helping them develop statistical reasoning skills related to interpreting reported research results, arguing based on quantitative evidence, and communicating results in the context of data. These skills have become more relevant during the COVID-19 pandemic due to the large volume of information the media have disclosed. Society must face many challenges regarding the impact that the disease has produced. The contingency due to the pandemic has shown that all the actors involved must rethink the role that education and educational institutions play in society, so it is necessary that, as a society, they continue to propose teaching strategies articulated with reality.

Limitations

This study focused on the case of a PhD course in which ten students participated; therefore, it presents a limitation regarding the generalizability of the results to other contexts. Another limitation is that given the type of study, it is impossible to establish that the teaching strategies implemented in the course were the cause of the transformation of students' perceptions. Therefore, more studies are required through experimental designs that confirm the relationship between teaching strategies and students' perceptions of them. We need further studies and courses in which the same strategies are implemented that consider situations and student populations in similar contexts.

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Annexes

Annex 1: Critical reading template example

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National Faculty of Public Health "Héctor Abad Gómez"

Reading report of an article 10%

Name: _____ Identity number_____

Consider the article: " **The suicide attempt in Ibagué: The silence of a voice for help1.** Based on the statistical information referred to there, answer the following questions:

1. **(Value: 1.25. Success in each numeral is worth 0.25).** Take the variable *Vital Status (Adolescence-Adult)* from Table 1 as a reference. Interpret the two confidence intervals of both categories, under the following scheme:
   a) What is the nature of the variable of interest?
   b) Which parameter is estimated for each category?
   c) Interpret both confidence intervals
   d) Using Table 1 as a reference, identify the nature variables polytomous qualitative
   e) Write a conclusion for the results of the family type variable (table 1). Include the confidence interval.

2. **(Value: 1.25. Correctness in each numeral is worth 0.25). Take** as reference the variable *dysfunctionality with the couple* according to the *year* in which the suicide attempt was reported *(2013-2014)* in Table 2. Interpret the confidence interval and the hypothesis test presented there, under the following scheme:
   a) Which are the variables that are analyzed, with their respective nature?
   b) Which parameter is estimated for the variables that you defined in the previous paragraph?
   c) Interpret the respective confidence interval indicating clearly, if there are differences and if so, their magnitude and in favor of whom?
   d) State the null hypothesis and the alternative hypothesis for the variables in question and the direction of the test.
   e) Make the decision based on the value of p.

3. **(Value: 1.25. Success in each numeral is worth 0.25).** Take as reference the variables *age* of the suspected suicide, in years, depending on the *dysfunctionality with the partner* (Yes-No) of Table 3. a) Which are the variables that are analyzed, with their respective nature?
   b) Which parameter is estimated for the variables that you defined in the previous paragraph?
   c) State the hypotheses, null and alternative, that are derived from the results presented in the penultimate column.
   d) State the decision according to the results that appear in the penultimate column.

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