




Article

# Innovating Statistics Education: The Design of a Novel App Using Design Thinking

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**Abstract:** Statistical education at university level faces significant challenges, particularly with the rapid advancements in technology and evolving teaching methods. Updating teaching methodologies for statistics in higher education is essential. Information technologies can greatly enhance the learning of statistical content, but many existing platforms are not well-suited for university contexts, either due to language barriers or how the content is presented (often confusing, with limited explanations or lacking context). It is crucial to have a student-centered platform that addresses these issues, ensuring an effective and efficient learning experience. This study introduces “EstApp”, an innovative mobile application prototype designed for teaching and learning descriptive statistics in university courses. The application was developed using the Design Thinking methodology, which emphasizes user experience and focuses on the needs of the end users. The design process involved stages of empathizing, defining, ideating, prototyping, and testing, culminating in validation through user tests with university students and professors. This study concludes that EstApp’s functionalities enhance understanding of (1) statistical models through interactive graphs and data visualizers; (2) probability concepts via a probability calculator; and (3) descriptive statistics through real-time data generation and visualizers.

**Keywords:** user-centered design; design thinking; user experience; statistics; higher education; mobile application



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## 1. Introduction

Statistics education faces significant challenges in the digital era, where the ability to analyze and interpret data has become an essential competency in various professional fields. Students encounter various challenges when learning statistics, such as understanding: (1) theoretical concepts and specific variables [1]; (2) statistical analysis methods (regressions, models, statistical tests) [2]; and (3) notations [2]. Traditional teaching methodologies focused on memorizing theorems and formulas may not sufficiently address students’ needs [3]. Several studies suggest that the effective integration of innovative technologies (systems, applications, generative artificial intelligences) can improve student engagement and learning experiences [3–8]. Despite the growing interest in incorporating technology into educational processes, statistics education still needs to exploit the potentialities that new digital tools can offer more fully. This article describes the development of an innovative mobile application aimed at transforming the teaching of statistics in higher education by applying Design Thinking principles.

Our research focused on the design and implementation of an application that not only facilitates statistical learning, but also enhances the educational experience by integrating interactive and personalized tools. These tools, developed through a Design Thinking approach, effectively adapt to the real needs of students and educators, improving both accessibility and understanding of complex statistical concepts.

This work is inspired by systematic reviews and empirical studies that highlight the effectiveness of mobile technology in education, offering a promising way to overcome the limitations of traditional teaching methods. By combining statistical education with advanced digital tools, our application is proposed as a disruptive model that could significantly influence statistical pedagogy.

This article will outline the design and development process of the app, examining how specific features of mobile technology can be exploited to facilitate more interactive and engaging statistical learning. In addition, we will discuss the challenges and opportunities that this innovative approach presents for statistics education in the context of higher education. Importantly, we will project the potential of our application to foster a deeper and more applied understanding of statistics among undergraduates.

The following article is structured as follows: Section 2 provides the theoretical background. Section 3 and 4 describe the methodology used and each of its detailed phases for elaborating the proposal. Section 5 presents the final development results. Section 6 details the discussions. Finally, Section 7 presents the conclusions and future work.

## 2. Theoretical Background

### 2.1. Teaching Statistics in Higher Education

In recent decades, statistical literacy has been highlighted as a key competency to promote social cohesion, enabling every educated citizen to navigate the era of data and information actively and thoughtfully [6]. As a result, many countries around the world have increased curricular expectations for learning statistics in schools, including Chile, where its teaching is promoted within the mathematics curriculum throughout schooling [7–9].

In this new landscape, statistical education at university level faces a new challenge regarding students entering higher education who have a greater familiarity with the discipline from an early age. This situation highlights an ongoing issue in terms of the necessary updating of content and teaching methodologies of statistics at this level, for which research in the field of statistical education offers valuable contributions. For example, the generation of modern methodological proposals for teaching statistics [10–12], the use of information technologies in the teaching and learning of statistics [13–15], and empirical results on the use of digital tools in learning the content [16–18], among others. Consequently, we face the challenge of incorporating technological tools into the teaching and learning processes of statistics, particularly in descriptive statistics.

### 2.2. Information Technologies in Education

Incorporating information technologies (such as online platforms, mobile applications, and video games, among others) into teaching and learning processes can facilitate students' acquisition of knowledge, due to the following:

- It generates greater interaction and participation from students: for example, mobile applications and video games can engage students more actively and participatively in their learning process, which can increase their motivation and commitment to the subject being taught [19].
- It fosters autonomous learning: technologies can allow students to learn at their own pace and in their own time, which can be especially useful for those with different learning styles or learning difficulties [20].
- It is possible to create simulations and visualizations: for example, mobile applications and video games can include interactive simulations and visualizations that help students understand abstract concepts more concretely and easily.

- Immediate feedback can be provided: technologies can provide immediate feedback to students on their performance, allowing them to correct errors and improve their understanding of descriptive statistics concepts.

In general, the use of technologies in education as an additional complement to the teaching process can improve the quality of learning, increase student motivation and engagement, and provide a more personalized learning experience. However, for this experience to be satisfactory and the use of technologies to be effective and efficient, it is relevant to design a platform centered on the student, their characteristics, and their needs [21,22].

### 2.3. Technology in Teaching and Learning Statistics

The rapid advancement of technological innovations in the field of statistics has two fundamental consequences. On the one hand, the technological world, industry, and society require the educational system to train citizens competent in the use of such technologies to adapt to the paradigm of the technological revolution [13,15]. On the other hand, the educational sector can and should take advantage of the contribution represented by emerging technologies, especially those that, according to research, report greater benefits for learning. Numerous studies recommend the use of technology in classes, especially dynamic software applications, programming, such as the R software (version 4.4.1) [17,18], or those designed for educational purposes [13,16], such as TinkerPlots [23], Fathom [24], or Gapminder [25].

However, the mere use of these software does not ensure that learning occurs. Traditionally, research has focused on physical artifacts, but there has been less interest in the use of technology as a cultural resource to promote interaction among students, teachers, and statistics [26]. Ben-Zvi et al. [6] have identified a set of design considerations for creating learning environments to promote the development of statistical thinking from a socio-constructivist perspective: (a) focus on developing core statistical ideas rather than tools and procedures, (b) use well-designed tasks to support the development of statistical reasoning, (c) use of real, realistic, and motivating datasets, (d) establish a classroom culture that encourages statistical arguments, (e) use assessments to monitor students' development of statistical learning and evaluate instructional plans, and (f) integrate the use of technological tools that allow students to explore and analyze data. While, as the authors note, these considerations do not constitute a recipe for ensuring the success of teaching statistics with the use of technology, they do provide guidance that any inquiry into this topic should consider favoring the significant achievement of learning.

Following this perspective, oriented toward collaborative learning with others, it has been found that technology can serve as an environment that promotes statistical inquiry and exploration [26], helps to understand and visualize concepts via simulation [10], stimulates conditions for communication and discussion [26], summarizes the time spent teaching procedures and devoting more attention to statistical concepts [15,17], and provides the world's largest database, such as the Internet [17].

### 2.4. User-Centered Approach to Develop New Applications

User-centered design is a design methodology that focuses on the needs and desires of the end users of a product [27]. In the context of educational platforms for learning statistics, this approach seeks to create interfaces and user experiences that are intuitive, easy to use, and engaging, so that students can learn effectively [28]. To achieve this, it is important to consider the following elements when designing a platform that is useful and provides a good experience for students:

- Designing for diversity. Users of a platform may have different needs and abilities. The design should be inclusive and accessible to all students, including those with disabilities [29].
- Simplifying the user experience. The design should be easy to understand and use for students, regardless of their level of experience or technical knowledge [21,30].

- Designing for retention. Students may have difficulty retaining information in an online environment. The design should include strategies to increase information retention, such as gamification and interactivity [29].
- Improving user motivation. Motivation is essential for effective learning. The design should include features that increase user motivation, such as immediate feedback and personalization of the learning experience [29].

In summary, user-centered design is essential for creating educational platforms that are effective and meet the needs of students. Through user research, defining users and their needs, prototyping, and evaluation, an educational platform can be created that is attractive, intuitive, and easy to use.

### 2.5. Related Work

Our research explores the integration of mobile devices in educational settings, identifying both existing solutions and gaps in the current market. This analysis, grounded in rigorous systematic reviews and empirical studies, reveals how mobile technology significantly enhances teaching and learning outcomes [31–33].

Firstly, a range of applications facilitate education without focusing on specific content areas. Examples include Kahoot [34] and Mentimeter [35], which are designed for general learning. In contrast, tools tailored explicitly to statistics education, such as Codap [36], Rossmanchance [37], Fathom [24], and ArtofStat [38], offer functionalities for performing calculations and creating graphical representations.

Despite these developments, our proposal identifies a significant gap. Currently, no application on the market combines general learning tools with advanced statistical functionalities. This integration represents a significant innovation with the potential to transform how statistics is taught and understood.

Supporting this perspective, a recent patent survey using the displacement tool uncovered patent CN114969660A [39], entitled “Online Interactive Dynamic Statistical Education Method (OIDSE), platform and device and storage medium”, was filed in 2022. This patent describes an interactive online platform that enables users to manipulate distribution parameters, generate data, and visualize it graphically, indicating a trend toward more dynamic and interactive educational solutions.

Furthermore, mobile devices facilitate a myriad of educational enhancements [40,41]. They allow students and educators to access content anytime and anywhere, overcoming traditional learning barriers and fostering a more adaptable learning environment. The interactive nature of mobile technology also makes learning more engaging, catering to a technologically adept generation. Through adaptive learning technologies, education can be personalized to meet individual student needs by monitoring performance and adjusting difficulty levels in real-time. This approach caters to diverse learning speeds and enhances academic performance [42].

Moreover, mobile technology promotes collaborative learning through shared applications and platforms that support group work and discussions. This not only improves learning outcomes but also enhances social and communication skills. Finally, integrating mobile devices into education is crucial for developing digital literacy skills and preparing students for future challenges in a technology-oriented professional landscape [43,44]. While various systems demonstrate the relevance of mobile devices in teaching, the proposed solution uniquely integrates general and specialized educational tools, setting a new standard for mobile learning in statistics.

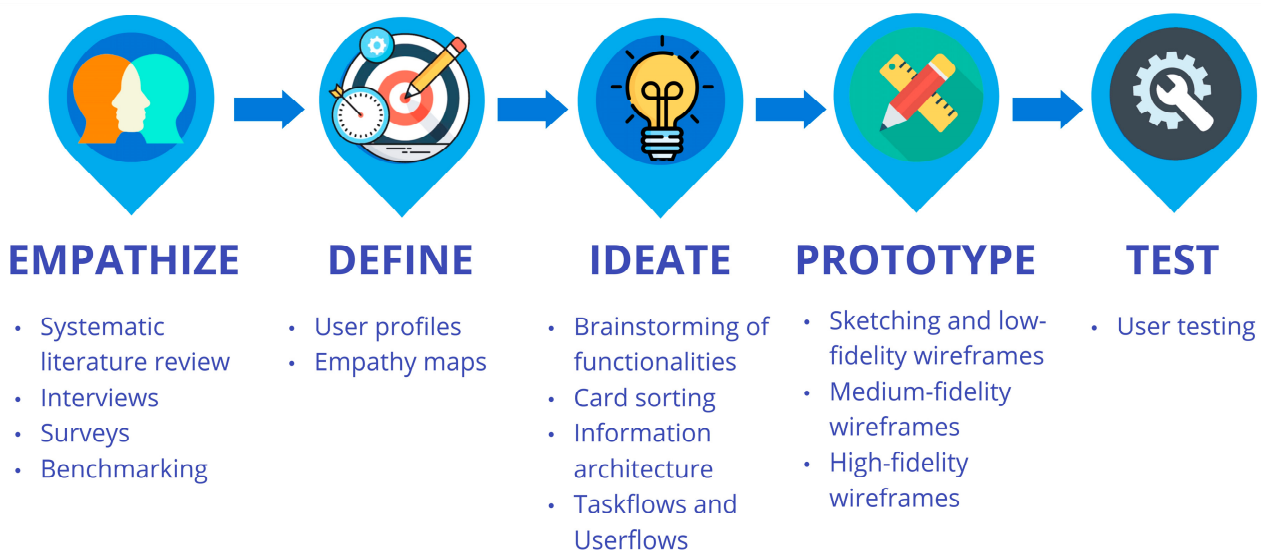
### 3. Methodology

Design Thinking is a user-centered methodology that aims to solve complex problems in a creative and innovative way. This approach is based on a deep understanding of user needs and analyzing the problems people face when performing actions to achieve a specific goal. The used scenarios are thoroughly analyzed to generate solution ideas, prototype, and test these solutions. Design Thinking can be used in the technology and

innovation fields for software development and computer applications as it allows for a better understanding of needs, requirements, and creates innovative software solutions, offering solutions that are intuitive [45,46]. It consists of a five-stage process:

- **Empathize:** This stage involves researching end users to identify their characteristics, expectations, needs, and difficulties in performing their tasks. The goal is to deeply understand the people for whom the product is developed, including their objectives, problems, limitations, desires, and emotions, as well as the context in which their actions occur, to design solutions that adequately respond to their needs.
- **Define:** This stage involves analyzing previously collected data to identify patterns and issues, which allows for a clear detailing of the difficulties and frustrations users face when trying to achieve their goals. The aim is to establish a detailed panorama of the problems, needs, and expectations of the users, providing a solid basis for defining the design requirements of the software product.
- **Ideate:** This stage focuses on generating a wide range of ideas and potential solutions to previously identified problems. The team promotes dynamics to create innovative ideas about the software product and its interaction, exploring various options without initially judging them. Then, the best proposal is selected, or a solution is developed that integrates the best features of the ideas developed.
- **Prototype:** This stage involves building tangible and simplified versions of the selected ideas, such as sketches or wireframes, to explore how they might work in practice. These prototypes allow for identifying design issues and making modifications before reaching the final solution, ensuring that the interfaces are usable, attractive, and aligned with user objectives. This facilitates the correction of design aspects without significantly affecting the project's development.
- **Test:** This stage focuses on evaluating the designed prototypes to obtain feedback and verify if they meet the needs and expectations of the users. Through these tests, the team gathers valuable information to correct and refine the prototypes until they reach the final proposal. Tests are conducted both with initial sketches and more elaborate prototypes, allowing for the fidelity to be raised and adjustments to be made efficiently and economically before the final implementation.

Figure 1 shows the activities we performed in each stage of Design Thinking to design EstApp. Table 1 provides a description of each activity performed [46].



**Figure 1.** Design Thinking process and activities for creating EstApp.

**Table 1.** Activities performed for creating EstApp.

Stage	Activity	Definition
Empathize	Interview	Direct conversation with people to collect information about who the users are, their needs, problems, and frustrations, to better understand the problem.
	Survey	A questionnaire that allows probing into the issues, needs, expectations, and actions people take to achieve their goals. It enables reaching many people located in different geographical areas.
	Benchmarking	Involves exploring multiple alternatives that have been formulated as solution options to the problem being addressed. Then, a comparative analysis is conducted to identify the positive and negative aspects of each proposal with the goal of developing a custom solution that considers the best aspects, practices, and standards.
Define	User profile	A method that synthesizes the characteristics, behaviors, needs, expectations, goals, challenges, and problems of a specific group of users.
	Empathy map	A method that visually and graphically synthesizes the thoughts, emotions, behaviors, and needs of a group of people.
Ideate	Brainstorming	A method for generating a set of ideas about the solution to the problems and obstacles people face in achieving their goals, improving the process and associated experience. In software development, this method is used to generate ideas about potential functionalities to include in the solution.
	Card sorting and information architecture	Card sorting is a technique used to organize and categorize information according to the users' perspectives. Participants group cards that represent concepts or elements, which helps designers understand how users structure information. This technique enables the development of information architecture, which is the logical structure and organization of content within a system, ensuring that users can navigate and find information intuitively.
	Taskflows and userflows	Taskflows describe the specific steps a user follows to complete a task in a product. On the other hand, userflows are visual representations of the path a user travels through an application or website to reach a goal, considering the interactions and decisions they make along the way.
Prototype	Low-fidelity wireframes	Involves creating simple and initial representations (usually paper sketches) of the solution and its interface. Low-fidelity prototypes are used to obtain quick feedback without investing too much time and resources.
	Medium-fidelity wireframes	Involves creating digital representations of the solution with design elements that will be part of the interface, but without details such as color, typography, or images.
	High-fidelity wireframes	Involves creating detailed and realistic representations of the solution and its interface. These prototypes closely resemble the final version of the solution in terms of appearance and functionality. They are used to obtain more accurate and valuable feedback due to the prototypes' similarity to the final product.
Test	User testing	Involves observing and evaluating the interaction of end users with the product design proposal. It allows for direct information from end users about the design proposal, identifies problems that occur during interaction, and thereby identifies opportunities for improvement and makes necessary corrections.

## 4. EstApp Design Process

### 4.1. Empathize Phase: Activities and Results

In the Empathize stage, a qualitative study was conducted involving interviews with a total of 14 participants, 8 students (who learned or are learning statistics at university), and 6 professors (who teach statistics) from the Pontificia Universidad Católica de Valparaíso (PUCV), Chile. The purpose of these interviews was to gain a deep understanding of users' experiences, needs, and perceptions regarding the learning and teaching of descriptive statistics in the university context. Appendix A shows the questions asked in the interviews. The findings revealed that, while students value the applicability of statistics, they face significant challenges such as data interpretation and a lack of motivation stemming from unengaging methodologies. On the other hand, professors reported varied experiences in teaching the discipline, highlighting the main obstacles to be difficulty in motivating student participation and grounding abstract concepts.

Additionally, a survey was conducted involving 440 students from diverse undergraduate programs at PUCV, including business administration, computer science, accounting, bachelors of science, biology, social work, and statistics, among others. The objective of the survey was to understand the needs of users (upper-level students) related to learning statistics, as well as their motivations and frustrations when facing any course related to descriptive statistics. The open-ended questions allowed for the identification of concerns related to unintuitive interfaces, lack of practical exercises, and decontextualized applications. On the other hand, Likert-type questions revealed a marked interest in applications that incorporate examples related to the area of study, attractive visualizations, and the ability to generate data.

Furthermore, a comparative analysis (benchmarking) of existing applications and tools for learning and analyzing statistics was conducted. Table 2 shows the comparative analysis between the applications Kahoot [34], Mentimeter [35], Codap [36], Rossmanchance [37], Fathom [24], and ArtofStat [38] considering 3 criteria:

1. Usability: high level (intuitive and easy-to-use interface), medium level (slightly confusing interface), low level (non-intuitive interface, difficult to use).
2. Language: high level (use of non-technical language that is easy to understand for non-experts), medium level (use of some technical concepts to explain), low level (use of technical and specific language, difficult to understand for those who do not know statistics).
3. Design: high level (pleasant and aesthetic interface), medium level (interface with some visually annoying elements), low level (unattractive and unfriendly interface for the user).

The results indicated that, while some applications like Kahoot [34] and Mentimeter [35] facilitate learning in the classroom, they lack advanced statistical functions. On the other hand, tools like Codap [36], Fathom [24], Rossmanchance [37], and ArtofStats [38] allow for data analysis but have unintuitive interfaces and a high degree of technicality.

Collectively, the findings from the Empathize phase provided a deep understanding of the needs, challenges, and motivations of students and professors regarding the learning and teaching of descriptive statistics. This information was useful for defining user profiles, empathy maps, and key requirements of the EstApp application in subsequent design process phases.

### 4.2. Define Phase: Activities and Results

During the Define stage, we developed two user profiles and two empathy maps, one for the student and one for the professor, to accurately capture their needs and expectations regarding the learning and teaching of statistics. The user profiles and empathy maps were created based on detailed information gathered through interviews and surveys, which provided a comprehensive view of the characteristics, challenges, motivations, and goals of both groups. For the students, the profile reflected aspects such as their motivations, study methods, technological skills, and the difficulties they face in understanding statistical

concepts. On the other hand, the professor’s profile focused on their teaching methods, the need for tools that facilitate the teaching of statistical content, and the challenges they face in teaching statistics.

**Table 2.** Benchmarking results (“good” (green color), “fairly good” (yellow color), and “bad” (red color)).

Application	Description	Usability	Language	Design
Kahoot (august 2023 version)	Mobile app that uses learning games to introduce a topic, review and reinforce content, and even conduct assessments.	Highly intuitive for all types of users.	Non-technical and easy to understand for anyone.	Pleasant design, appropriate colors, and icons.
Mentimeter (august 2023 version)	Online web tool used for asking questions, conducting surveys, and playing games with an audience (students).	Highly intuitive for anyone to use.	Non-technical language, easy to understand for anyone.	Pleasant design, appropriate colors, and icons.
Codap (august 2023 version)	Educational software that serves as a tool for data analysis.	Intuitive and contains aids for people who are not specialized in statistics.	Easy language for anyone who is not familiar with technical statistical terms.	Aesthetic, consistent colors, and software identity.
Rossmance (2021 version)	Website containing various applets (small programs with specific tasks) on statistics topics.	Without prior knowledge in statistics, it is difficult to use.	All language used is very technical.	Poor design. Just text with a basic font.
Fathom (2018 version)	Dynamic software aimed at teaching data analysis and statistics.	Not intuitive at all, no tutorials in the software, functionalities are not explained. Very difficult to use for a first-time user.	All language used is very technical, and there is no help to understand the concepts shown in the software.	Not aesthetically pleasant, but not poor either.
ArtofStat (2022 version)	Web app that allows for interactive exploration of statistical concepts. Allows for constructing graphs, obtaining summary statistics, finding probabilities, obtaining confidence intervals, or fitting linear regression models.	Not entirely intuitive to use all offered functionalities, as some prior understanding of statistical concepts is required.	When interacting with certain functionalities, technical jargon knowledge is required to use them properly.	Pleasant design, consistent colors, and app identity.

The empathy maps complemented the profiles by deeply exploring the feelings, thoughts, motivations, behaviors, and concerns of students and professors, highlighting how these factors influence their educational experience. This information was crucial for guiding the UX design of the “EstApp”, to include functionalities that effectively responded to the identified needs. Figure 2 shows the “student” user profile, while Figure 3 shows the empathy map for the same profile.

#### 4.3. Ideate Phase: Activities and Results

In the Ideation stage, we conducted a brainstorming session with the goal of identifying and detailing the key functionalities of “EstApp”. As a result of this activity, 13 functionalities were identified and extensively analyzed and detailed. From these functionalities, we decided to design EstApp in three versions, free, light paid, and premium paid, allowing different levels of access according to the needs and resources of the users (teachers and professors). Appendix B shows the results obtained after the brainstorming session. Additionally, an open card sorting exercise was performed using 18 cards (based on information related to the key functionalities identified in the brainstorming), with the participation of 82 representative undergraduate students, which effectively organized and structured the application’s information. The results of this card sorting were crucial for creating the information architecture of “EstApp”. Appendix C shows the information architecture created. Finally, five specific userflows were designed for four of the functionalities considered most valuable and attractive for the first version of the application:

the Intelligent Assistant (IA tutor), the Data Visualizer, the Probability Calculator, and the Data Generator. This approach ensured that the most impactful and useful functionalities were prioritized in the initial development, enhancing the UX. Figure 4 shows the userflow designed for the “Data Generator” functionality.

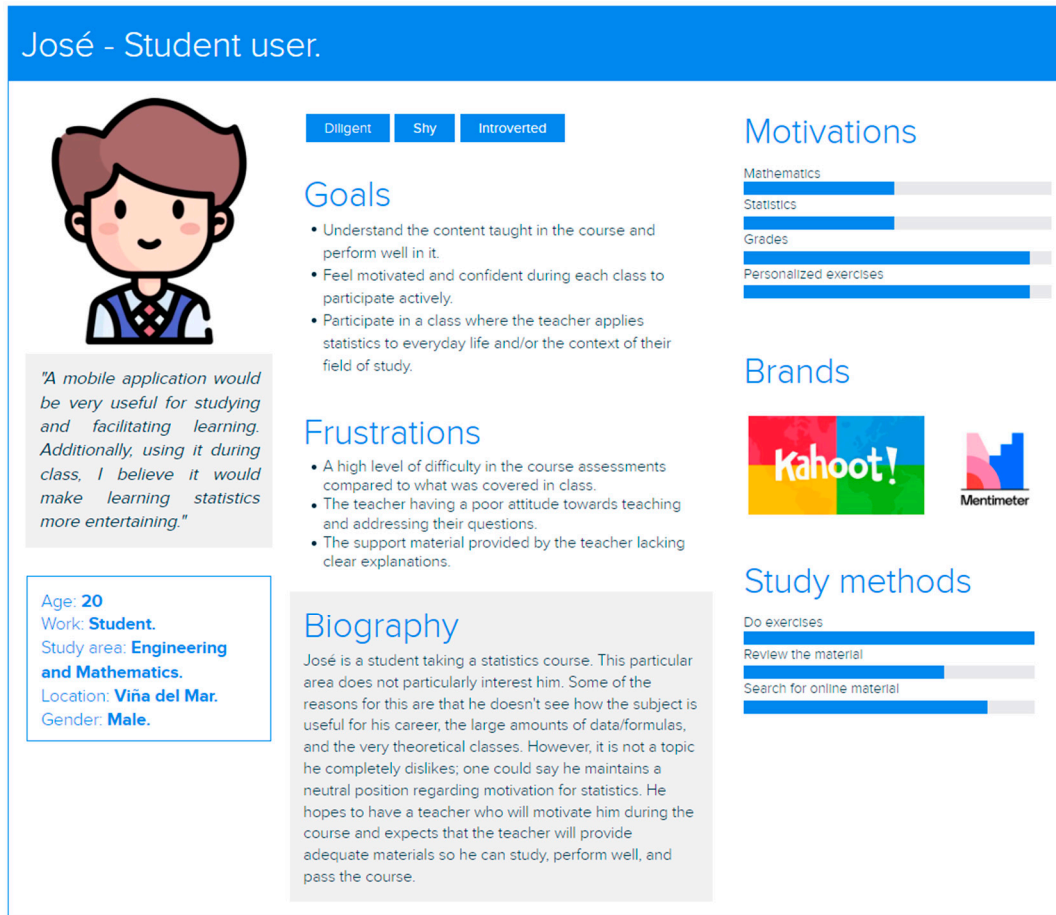


Figure 2. “Student” user profile.

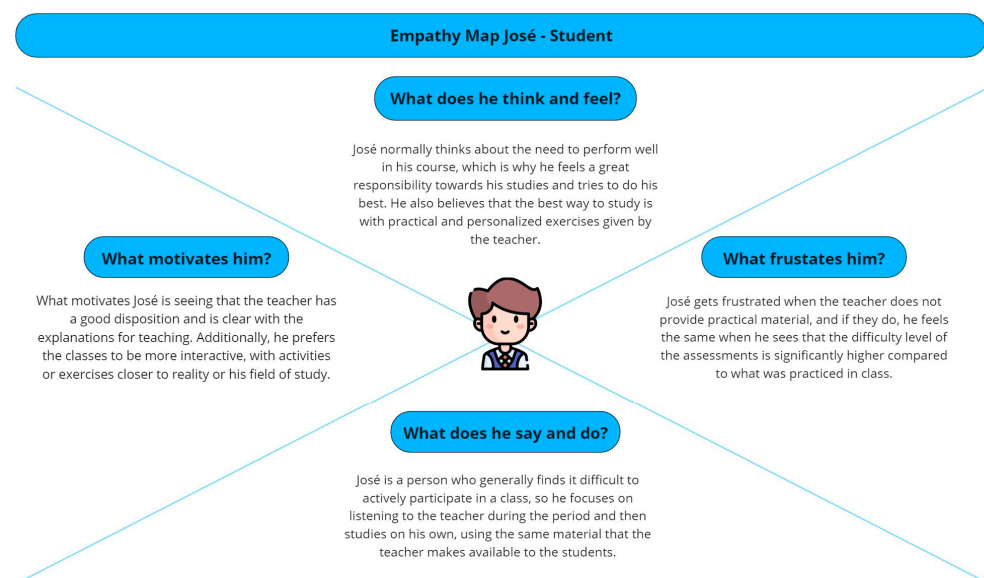
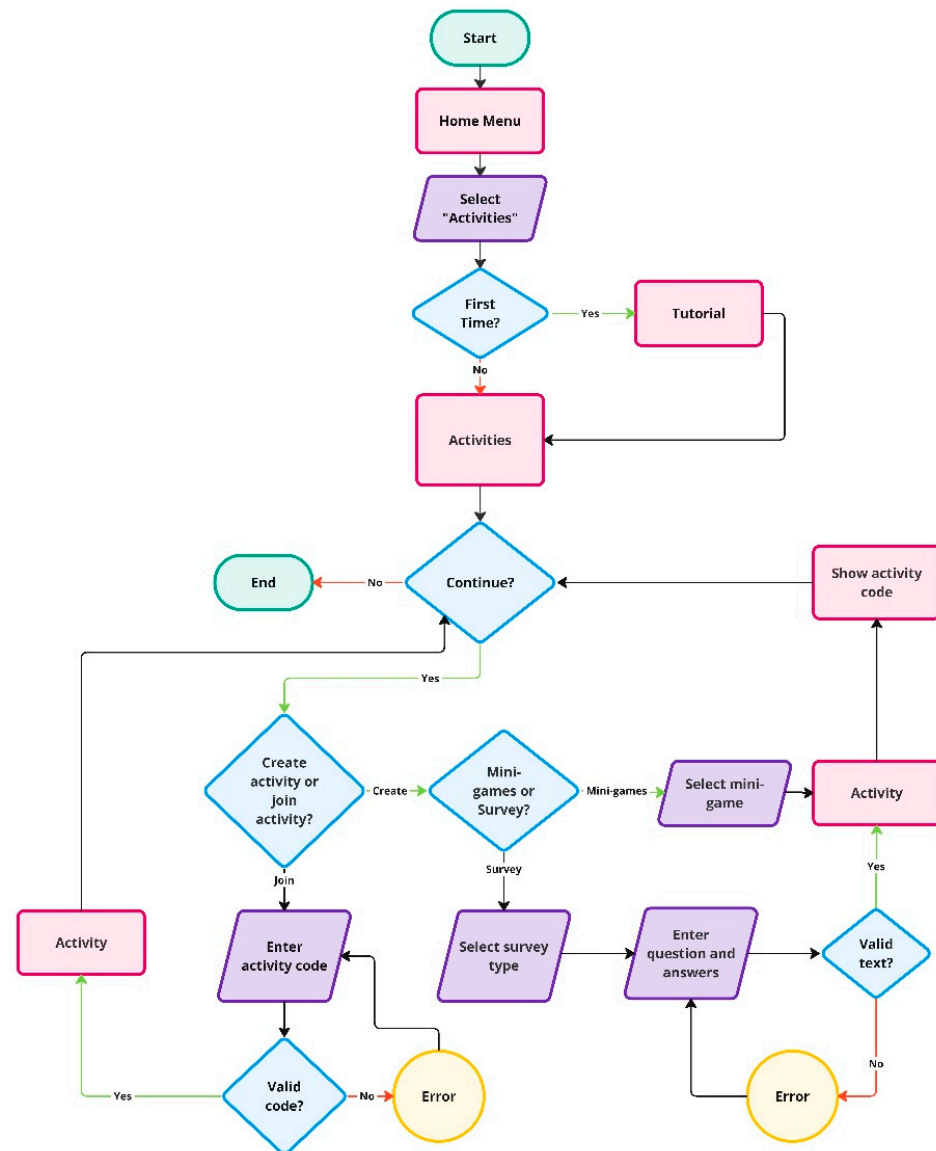


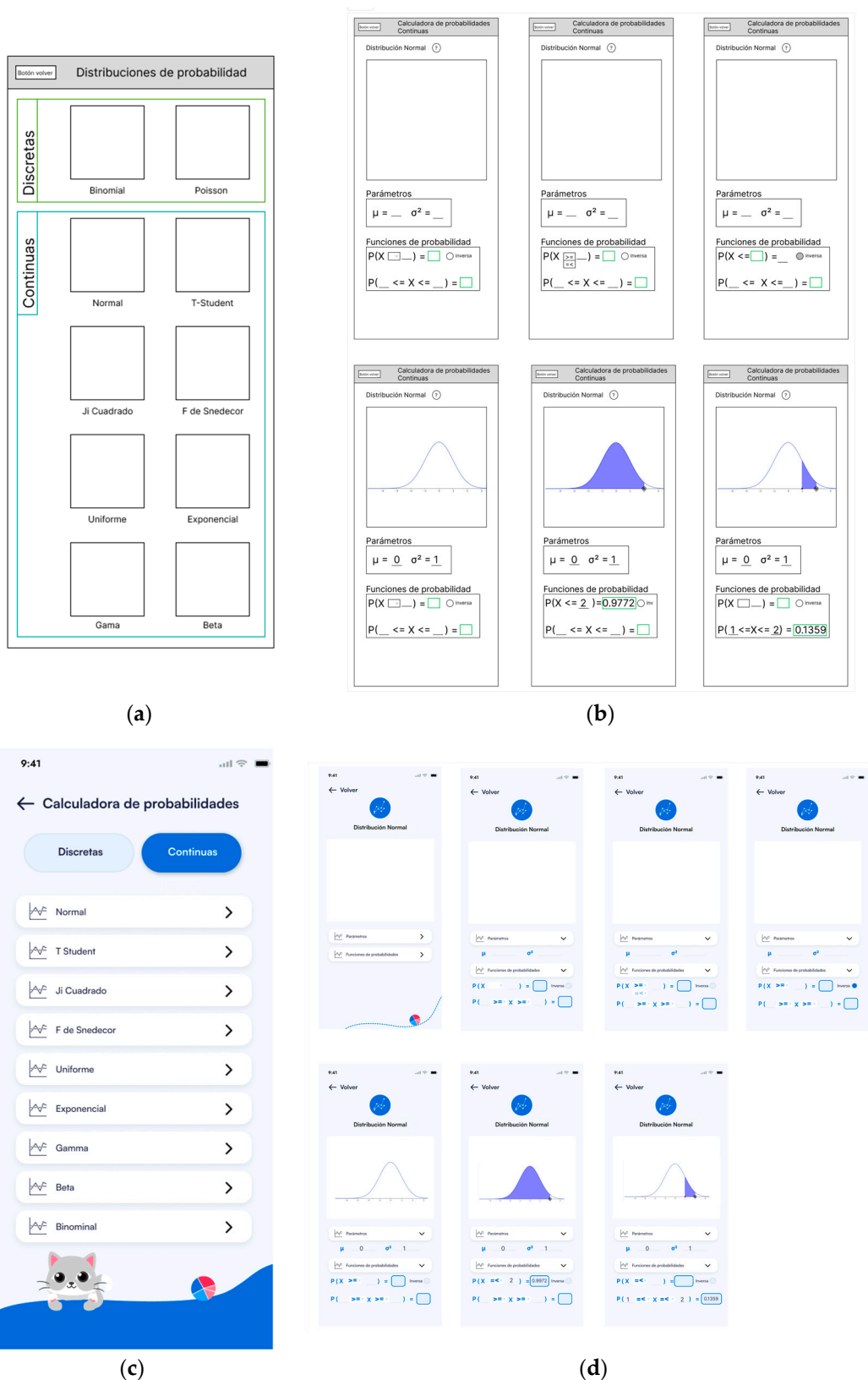
Figure 3. “Student” empathy map.



**Figure 4.** Userflows for “Data Generator” functionality.

#### 4.4. Prototype Phase: Activities and Results

During the Prototyping phase, we began the process of visually representing the ideas generated during the Ideation phase, starting with the creation of low-fidelity wireframes. These initial wireframes served as basic sketches that captured the general structure and flow of the four most valuable functionalities identified: Probability Calculator, Data Generator, Data Visualizer, AI Tutor, and Report Generation. The low-fidelity wireframes focused on establishing the layout and navigation without complex graphic details, facilitating rapid iteration and adjustment of the initial concepts. Subsequently, we moved on to the creation of digital wireframes in medium fidelity using the Figma tool. These wireframes included more details, such as basic iconography and visual hierarchy, providing a closer look at what the final application would look like. Finally, high-fidelity wireframes were developed, integrating all the visual elements, including colors, final typography, and interactive behaviors, closely resembling the final product. Figure 5 illustrates an example of the prototyping process for the Probability Calculator functionality, highlighting the design evolution from its initial conception to the final version.



**Figure 5.** Prototyping process for the “Probability Calculator” functionality. **(a)** Medium-fidelity: Probability Calculator—menu. **(b)** Medium-fidelity: Probability calculator—continuous variables, normal distribution. **(c)** High-fidelity: Probability Calculator—menu. **(d)** High-fidelity: Probability Calculator—continuous variables, normal distribution.

#### 4.5. Test Phase: Activities and Results

During the Test stage and to identify areas for improvement in “EstApp”, we conducted a user test with undergraduate students who have taken at least one statistics course. The test consisted of 25 questions, divided into 7 demographic questions, 3 open-ended questions for 4 scenarios (Question 1: Do you understand the functionality presented in the wireframes?; Question 2: Regarding the graphs shown, do you understand the information displayed?; and Question 3: Which elements did you find confusing?) and a final questionnaire to assess the students’ perceptions and experiences. The demographic questions aimed to identify the participants and their level of knowledge in statistics along with the educational support tools they had previously used. For the scenarios, we used the high-fidelity wireframes designed in the previous Prototyping stage, evaluating the following functionalities: (1) Probability Calculator; (2) Data Generator; (3) Data Visualizer: Histogram; and (4) Data Visualizer: Boxplot.

The test was conducted in person at the facilities of the Pontificia Universidad Católica de Valparaíso with the help of Google Forms. A total of 17 students participated. Of the participants, 88.3% were students of statistical engineering and 11.8% were from the mathematics area. Most of the students who participated in the test were in their 6th semester (35.3%) and 9th semester (23.5%). Of these students, the majority (87.5%) had taken at least two statistics courses. To learn about the educational support tools the students used inside and outside of class, a question was included with some of the options obtained from benchmarking and other known platforms (see Section 4, Section 4.1). The most used support tools by the students were Wolfram Alpha (94.1%) and Geogebra (88.2%), followed by Kahoot (41.2%) and Rpubs (23.5%), while Brilliant and Mentimeter were not used.

In “Scenario 1: Probability Calculator” (see Appendix D, Figure A3), 94.1% of the students clearly understood how to enter the necessary parameters and how to interpret the resulting graph from a binomial distribution. Only 5.9% showed limited understanding. Additionally, 64.7% found no confusing elements in the interface, 11.8% mentioned the lack of textual definitions for the variables, and another 11.8% expressed confusion related to the colors and graphical presentation. For “Scenario 2: Data Generator” (see Appendix D, Figure A4), 82.4% of the students had a positive opinion about the design, navigation, and terminology. However, 29.4% suggested specific improvements, such as restructuring the probability presentation and reducing the excessive use of the color blue in the design. Regarding understanding the experiment, 81.25% of the students understood how to perform it, while 18.75% had doubts and suggestions about the presentation of results and parameters. A total of 46.7% had issues with the presentation of results and navigation for setting parameters.

In “Scenario 3: Data Visualizer: Histogram” (see Appendix D, Figure A5), 82.4% of the students had a positive opinion about the design and navigation, highlighting the clarity and ease of use. In total, 23.5% suggested specific improvements, such as adding more colors and better explanations of certain functionalities. A total of 17.6% were confused about the histogram functionality, and while 56.3% found no confusing elements, 43.8% mentioned problems with the interface and data presentation. Finally, in “Scenario 4: Data Visualizer: Boxplot” (see Appendix D, Figure A6), all students understood the functionality and the information presented. In total, 91.7% found no confusing elements, while only 8.3% suggested improvements to enhance interface comfort and clarify additional terminology.

The overall perception of the students with the application was mostly positive, showing that most of them correctly understood the functionalities displayed during the test and how to interact with the application. However, the students made suggestions for improving the application, including changing the way results are delivered in the application and minor interface changes, such as adding a greater variety of colors.

Before concluding the test, we conducted a questionnaire to evaluate the students’ perceptions and experiences after reviewing the designed wireframes, including the following questions:

- P1: Do you think the functionalities of the application are easy to use? (Likert-type question, scale from 1: very difficult to 7: very easy.)
- P2: Do you think the functionalities of the application are useful? (Likert-type question, scale from 1: very useless to 7: very useful.)
- P3: How do you feel about the amount of information displayed on each view/screen? (Open-ended question.)
- P4: What would you suggest improving the application? (Open-ended question.)
- P5: Do you think the application could be useful for probability and statistics subjects? Why? (Open-ended question.)

Regarding question P1, most users found the application's functionalities easy to use, with 94.1% indicating that the application was easy or very easy to use. Regarding question P2, all participants (100%) found the functionalities of the application very useful. In relation to question P3, 43.8% of the students considered the amount of information shown to be sufficient and accurate; 25.0% of the students mentioned that the information was clear and understandable, and 18.8% of the students had a generally positive perception of the amount of information, highlighting its usefulness and speed for working. Finally, 12.5% of the students suggested improvements, especially in the presentation of the histogram charts and the inclusion of more functionalities.

Regarding question P4 (suggestions for improving the application), 35.3% of the students considered the application complete, easy to use, and had no specific suggestions for improvement. In total, 29.4% of participants suggested improvements in visual presentation, such as changing the color palette, improving typography, and adding more visual elements, while 35.3% of users suggested adding functionalities or features such as rewards, result summaries, additional explanations, sections for data cleaning, and customization of charts.

Finally, in relation to question P5, nearly half of the students (47.1%) considered the application useful for understanding charts and data analysis. A total of 23.5% of the students mentioned the accessibility and practicality of the application on mobile devices as a significant benefit. Still, 29.4% of the students indicated that the application was especially useful for basic levels of statistics and probability, highlighting its utility in primary and secondary education.

## 5. Results: EstApp

The "EstApp" application was designed with the aim of improving the teaching of descriptive statistics at university level by providing an interactive and user-friendly interface to facilitate the understanding of complex concepts. A module has been designed for data collection through random simulators that emulate games of chance, such as flipping a coin, spinning roulette wheels, and drawing cards. This functionality not only facilitates the generation of data for subsequent analysis but also adds a playful component to the learning process, motivating students to actively participate. Each student can have a profile that evolves as they engage in game-based activities, like content progression in platforms like "Duolingo". Additionally, we have designed a module that allows the configuration of surveys to collect student data through multiple-choice, open-ended, and true or false questions, among others. These data are input for visualization through graphs generated automatically through the application.

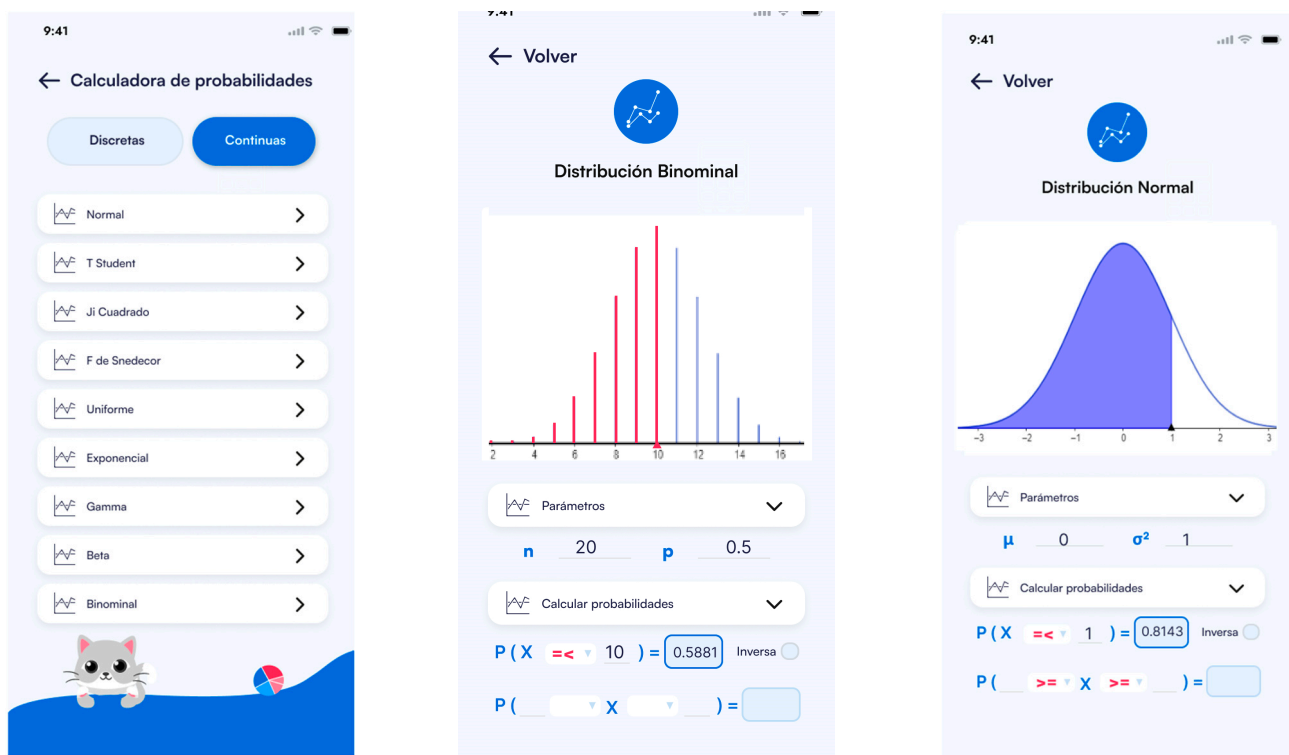
On the other hand, "EstApp" features a chart generator that allows for varied data visualization. Among the types of charts available are bar and pie charts for qualitative variables, histograms, and box plots for quantitative variables. This generator can graph up to five variables simultaneously, like the visualization capabilities of CODAP. Furthermore, we believe it is useful to incorporate a function to support the loading of real or simulated databases by the teacher, allowing the use of preexisting data as inputs for specific analyses.

As support for students, we have designed a section dedicated to the interaction and deduction of statistical formulas, organized by macro content areas such as descriptive statistics, probabilities, and inference. This functionality will help students better

understand the formulas and their applications in different contexts. Along with this, a probability calculator was designed to find values and quantiles associated with common probability distributions in introductory statistics courses. This tool is inspired by probability calculators like GeoGebra's. Finally, given the significant progress and use of artificial intelligence tools, we believe it is useful to support student learning with a virtual tutor. We designed a chat-style artificial intelligence tutor that allows students to interact and delve into the content of interest. Below, the main features of the application are described in detail, accompanied by screenshots to illustrate its different sections.

### 5.1. Probability Calculator

One of the remarkable features of EstApp is the Probability Calculator, which allows users to calculate probabilities and quantiles for a variety of statistical distributions. Users can input specific parameters for each distribution and select different inequality options to calculate the corresponding probabilities (see Figure 6).



**Figure 6.** EstApp “Probability Calculator” functionality.

### 5.2. Data Generator

The Data Generator in EstApp includes random experiments and mini-games designed to facilitate the understanding of statistical concepts through data simulation. Available experiments included coin tosses, dice rolls, roulette, card selection, and ball drawing. The mini-games included options such as Snake, Tetris, crosswords, math quizzes, reaction tests, and dart throws, generating detailed statistics on user performance (Figures 7 and 8).

### 5.3. Data Visualizer

EstApp’s Data Visualizer allows users to import files in TXT, CSV, and Excel formats or data from the “Data Generator” module to generate various types of charts. Available charts include pie charts for categorical variables, histograms, box plots, and bar charts, among others. This module provides customization options and allows saving the charts in different image formats (Figure 9).

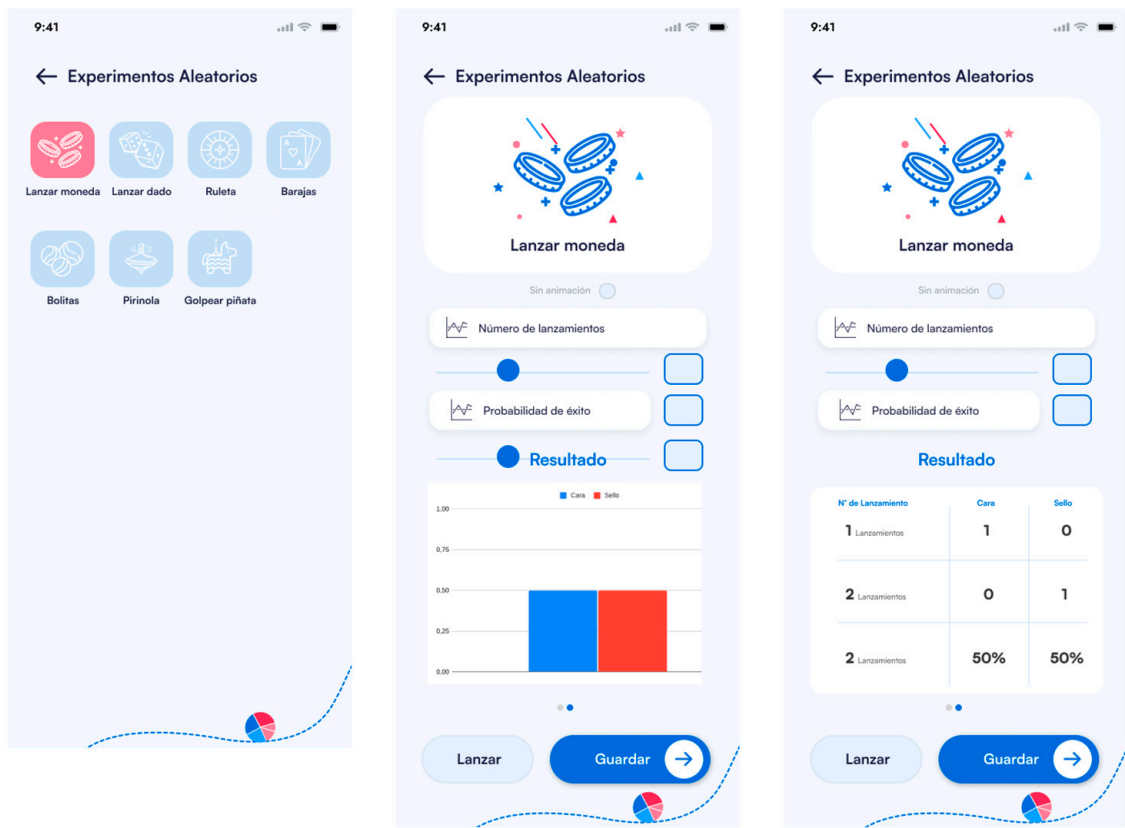


Figure 7. EstApp “Data Generator” functionality, random experiments.

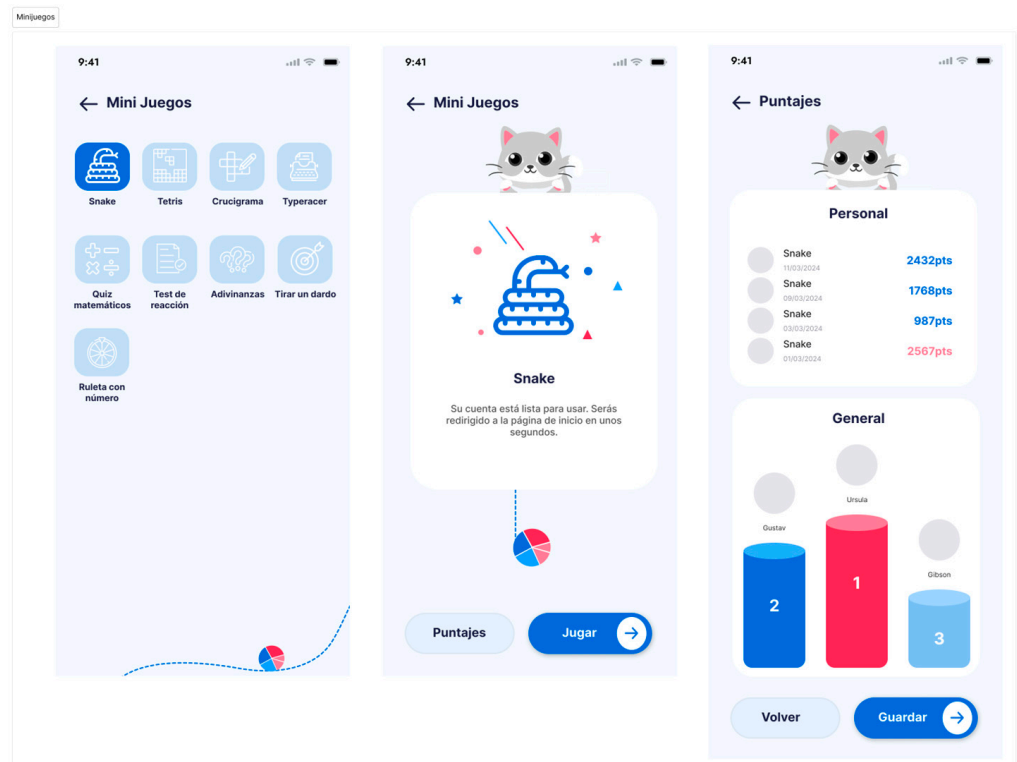


Figure 8. EstApp “Data Generator” functionality, mini-games.

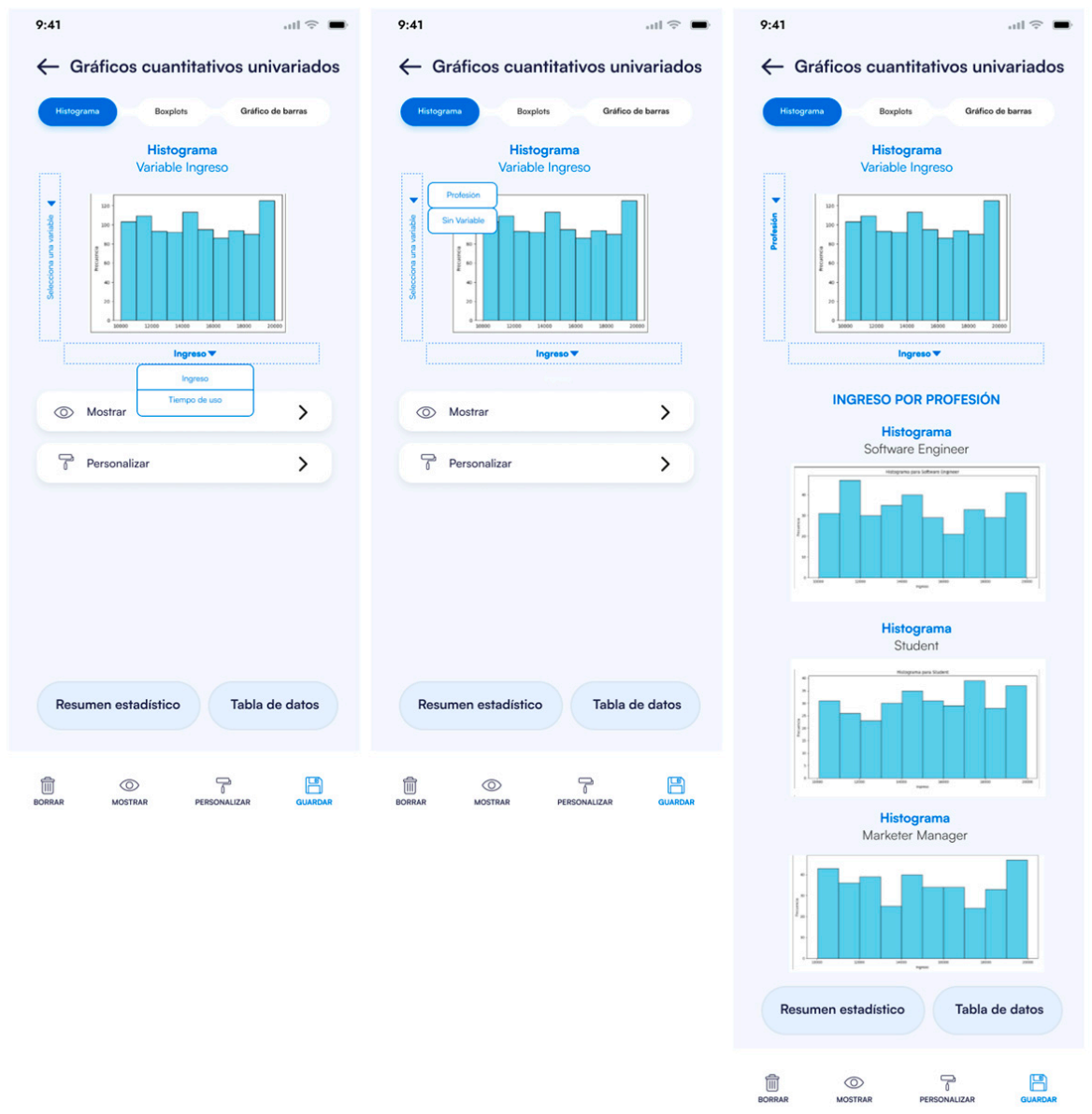


Figure 9. EstApp “Data Visualizer” functionality.

#### 5.4. AI Tutor and Report Generation

EstApp includes a chat-style AI Tutor that allows students to examine deeper into content and resolve specific questions. The AI Tutor will answer questions related to concepts, data, and statistical exercises. Internally, the application will use external AI services to answer students’ questions. Students will be able to interact with the tutor in a chat format, asking about formulas, interpretations of graphs, definitions of statistical terms, or steps to solve problems. Students will also be able to ask the AI Tutor about statistical data types, allowing them to clarify concepts and receive detailed explanations in real time, which facilitates immediate understanding of complex topics. In addition, students will be able to upload documents in PDF format and ask the AI Tutor about the content, such as asking it to summarize sections or explain specific concepts displayed in the document. Additionally, the application generates individual and group reports on the usage and progress in learning activities, providing valuable insights for teachers and professors (Figure 10).

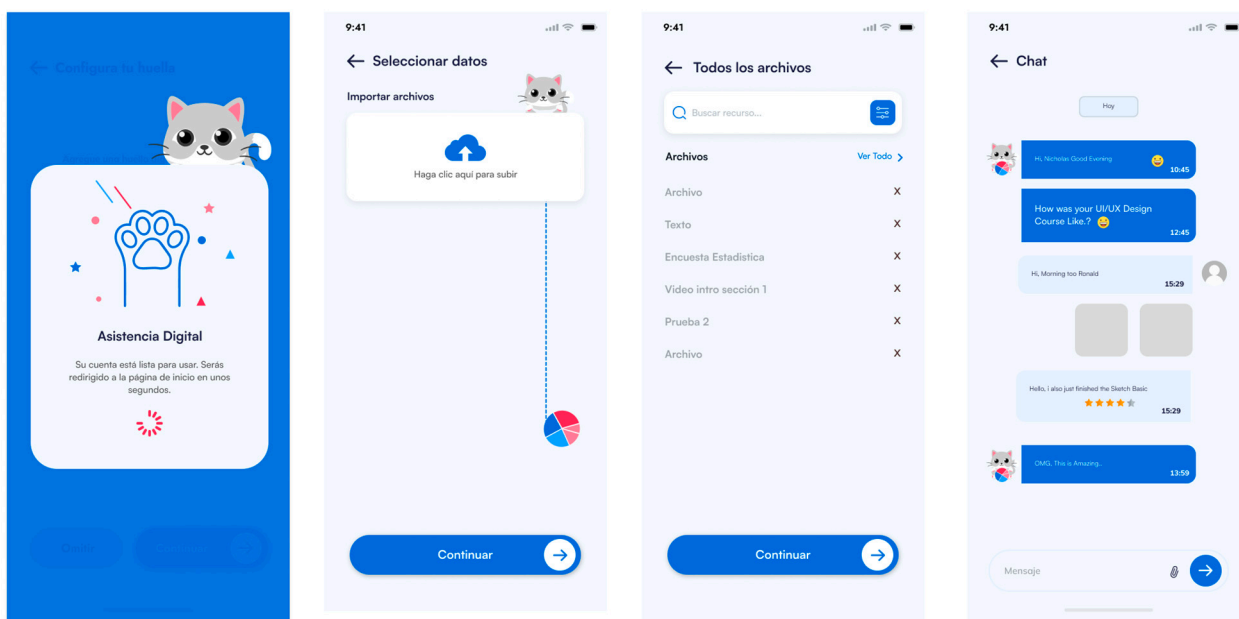


Figure 10. EstApp “AI Tutor and Report Generation” functionality.

## 6. Discussions

### 6.1. EstApp’s Functionalities and Their Impact on Education

To design EstApp, we discussed a variety of functionalities to include, focusing on designing those we thought most useful and valuable for teaching and learning statistics. Table 3 shows the functionalities designed for EstApp, along with the technical description of each and the potential impact they could have on students’ education in statistics.

Table 3. Technical description and impact on education of EstApp functionalities.

Functionality	Technical Description	Impact on Education
Probability Calculator	Calculates probabilities for various statistical distributions (Binomial, Poisson, Normal, T-student, Chi-square, F-distribution, and Exponential, among others). Users can enter specific parameters to calculate accurate probabilities.	Reinforces probabilistic reasoning by allowing students to interact directly with statistical distributions, experiment with variables, and obtain immediate results. Real-time practice aids in understanding theoretical concepts and conditional probabilities, improving retention and mastery of the subjects.
Data Generator	Incorporates random experiments (such as coin tosses, dice rolls, and roulette spins) and mini-games (such as Snake, Tetris, and quizzes) that generate real-time data. The data can be visualized and analyzed directly in the application.	Introduces a “gamified” approach to learning statistics, making abstract concepts more understandable. Students can experiment with the data and observe how their decisions impact the outcomes, promoting active and meaningful learning. This keeps students motivated, improving their engagement and participation.
Data Visualizer	Imports files in TXT, CSV, and Excel formats, and create charts such as histograms, bar charts, pie charts, box plots, and more. Students can customize the charts and visualize different relationships between variables.	Promotes statistical literacy by allowing students to see graphical representations of data, making it easier to understand trends and variability. By manipulating different variables and chart types, students develop analytical skills and a greater ability to interpret data visualizations.

Table 3. Cont.

Functionality	Technical Description	Impact on Education
AI Tutor	Offers real-time personalized assistance by answering questions about formulas, statistical concepts, and steps to solve problems. The AI Tutor also provides answers based on PDF documents uploaded to the app.	The AI Tutor acts like a “professor”, guiding students through their learning process. This promotes autonomy and self-directed learning, as students can immediately clarify doubts. Personalized feedback allows students to correct mistakes in real-time, reinforcing learning and fostering self-efficacy.
Surveys and Data Collection	Create custom surveys with open-ended, multiple-choice, or true/false questions, and collect data that can later be analyzed and visualized within the app.	This feature involves students in the practical process of data collection and analysis. They learn to interpret data and analyze statistical results, improving their understanding of statistical methods.
Report Generation	Generates reports based on student performance, tracks their progress throughout the course, and provides detailed feedback on areas where improvement is needed.	This fosters self-regulated learning, as students receive detailed insights into their performance, allowing them to identify weaknesses and areas for improvement. These reports also enable professors to monitor student progress and offer timely interventions.

On the other hand, the use of EstApp enables professors to implement modern and innovative teaching methodologies (such as constructivism [6] and experiential learning [6]). For instance, active learning is encouraged, allowing students to engage in their own learning process and deepen their understanding through interaction with EstApp features and real-world problem-solving. The “Data Generator”, “Probability Calculator”, and “Data Visualizer” features allow students to directly interact with statistical concepts by generating real-time data and visualizing results. This promotes “learning by doing” rather than merely receiving information passively, and it enables them to work with real or simulated data, analyze graphs, and practically comprehend relationships between variables. In addition, the learning process becomes adaptive and personalized using the AI Tutor, as the interaction is designed to the student’s needs and guides them in reflecting on their incorrect responses.

As mentioned in Section 2.3, Ben-Zvi et al. [6] identified six design considerations for creating learning environments that promote the development of statistical thinking. For the design of EstApp, we applied these six guidelines to propose features that facilitate the students’ learning process. Table 4 shows a mapping between the six design characteristics proposed by Ben-Zvi et al. [6] and the functionalities designed in EstApp.

### 6.2. The Iterative Process for Designing “EstApp”

During the Design Thinking process, we applied the five phases by carrying out various activities (see Sections 3 and 4). To ensure the correct application of each phase, we collaborated with diverse stakeholders, including university students, statistics professors, IT professionals, UI/UX designers, and researchers.

For the Empathize phase, we conducted interviews and surveys with university students and professors to understand their difficulties and expectations regarding learning statistics. To validate the information obtained, we performed a qualitative analysis of the responses, allowing us to identify patterns and recurring problems. In the Define phase, we analyzed the identified patterns to define the main problems. To validate these problems, we conducted a second round of reviews with the participants, where we discussed preliminary problem definitions. This feedback helped confirm that the students’ and professors’ “pain points” and frustrations were correctly identified. Additionally, the definitions were reviewed by experts in pedagogy and interface design to ensure that the needs were adequately addressed.

**Table 4.** Mapping between the six design characteristics proposed by Ben-Zvi et al. [6] and the functionalities designed in EstApp.

Design Consideration Proposed by Ben-Zvi et al. [6]	EstApp Functionalities	How It Was Considered in the Design of EstApp
Focus on developing core statistical ideas rather than tools and procedures	Probability Calculator, Data Visualizer, AI Tutor	EstApp focuses on fundamental statistical concepts, such as distributions and probabilities, through tools that allow students to understand and explore statistical ideas.
Use well-designed tasks to support the development of statistical reasoning	AI Tutor, Surveys, Data Generator	The tasks within EstApp are designed to guide students in solving real-world statistical problems. The AI Tutor provides immediate and personalized feedback, fostering the development of statistical reasoning.
Use of real, realistic, and motivating datasets	Data Visualizer, Data Generator, Data Upload (TXT, CSV, Excel)	EstApp enables students to work with both real and simulated data, encouraging the practical application of statistical concepts.
Establish a classroom culture that encourages statistical arguments	AI Tutor, Interactive Feedback	The AI Tutor promotes dialogue and critical thinking by having students ask questions about topics they do not fully understand, fostering a culture of autonomous and personalized learning.
Use assessments to monitor students' development of statistical learning and evaluate instructional plans	Progress Reports, Surveys, AI Tutor Feedback	EstApp monitors students' progress through reports that track their performance on tasks, providing feedback. Teachers can use this information to adjust lessons and improve learning outcomes.
Integrate the use of technological tools that allow students to explore and analyze data	Data Visualizer, Probability Calculator, Data Generator, AI Tutor	EstApp integrates technological tools allowing students to manipulate data and explore results. These tools encourage autonomous exploration and data analysis, facilitating active learning.

For the Ideation phase, we generated multiple ideas for possible functionalities of the application. To validate these ideas, we conducted a brainstorming session with experts and end users. The results of this exercise helped confirm that the selected functionalities (such as the Probability Calculator, Data Visualizer, and AI Tutor) were relevant and appealing to both students and professors. This validation also included a technical feasibility analysis with the development team. During the Prototyping phase, a team of UX/UI designers created low-, medium-, and high-fidelity wireframes to represent EstApp's functionalities. The medium-fidelity wireframes were validated through quick usability tests with real users, who provided feedback on the clarity and navigation of the design. Finally, for the Testing phase, the high-fidelity wireframes were validated through formal usability tests. In these tests, students and professors interacted with the prototype, confirming that the interface was intuitive and that the functionalities aligned with their expectations and needs.

Compared to applications like Kahoot and Mentimeter, which focus primarily on immediate interaction and participation through live quizzes and surveys, EstApp offers a more comprehensive and in-depth experience for teaching statistics by providing tools such as the Probability Calculator and Data Visualizer. These functionalities are designed not only to capture students' attention but also to improve their statistical reasoning through interactive data visualization and real-time probabilistic calculations. On the other hand, while tools like Codap, Rossmance, Fathom, and ArtofStat also include simulations and visualizations, EstApp stands out for its user-friendly and interactive interface that incorporates gamification elements, as well as its AI Tutor, which assists students in their learning process.

### 6.3. Lessons Learned and Challenges Encountered

The design of any application involves a series of challenges and experiences. When designing EstApp using Design Thinking, we had to learn from other disciplines (statistics and UX/UI design) and we reaffirmed the importance of including end users throughout the design process. Tables 5 and 6 provide a summary of the lessons learned and the challenges encountered (respectively) in various aspects related to the design of EstApp.

**Table 5.** Lessons learned from designing EstApp using Design Thinking.

Aspect	Lessons Learned
User research	<ul style="list-style-type: none"> <li>- It is useful and advisable to conduct more than one experiment to gather information from different sources and complement the findings. In our case, we conducted both interviews and surveys.</li> <li>- It is crucial to work with representative users from diverse profiles, such as professors and students, to understand their needs, frustrations, and expectations.</li> </ul>
Prototype validation	<ul style="list-style-type: none"> <li>- Creating low-, medium-, and high-fidelity wireframes allowed us to iterate on EstApp's design, make early corrections, and receive valuable feedback before implementing the mobile application. This helped reduce the costs associated with modifying an already built software due to changes in the interface and/or features that users may not find useful or easy to use. Validating with users through digital prototypes was resource-efficient and helped us identify usability/UX issues (related to navigation, interface, and feature usage).</li> </ul>
Flexibility of Design Thinking	<ul style="list-style-type: none"> <li>- Given the flexibility of Design Thinking to iterate and/or repeat its phases, we were able to continuously adjust our ideas based on real user data and feedback. This allowed us to validate that EstApp includes features that meet the real needs of students and professors.</li> </ul>
Personalized education	<ul style="list-style-type: none"> <li>- Incorporating interactive and personalized elements into EstApp's design (mini-games, dynamic data collection, AI Tutor) had a positive impact on students, as they mentioned that the app was useful and easy to use. We believe these components will assist and motivate students during classes, and we expect them to actively participate in their learning process.</li> </ul>
Multidisciplinary collaboration	<ul style="list-style-type: none"> <li>- Involving various stakeholders (statistics professors, students, academics, researchers, programmers, UX/UI designers) allowed us to balance user needs and design a feasible and effective solution (in terms of interface and programming), benefiting both those who teach and those who learn.</li> </ul>

**Table 6.** Challenges faced when designing EstApp using Design Thinking.

Aspect	Challenges Encountered	How We Addressed Them
User research	Students and professors had very different needs and expectations, making the analysis of the information gathered from interviews and surveys challenging. We obtained a lot of valuable data, but it took time to consolidate and prioritize.	We created two user personas and two empathy maps, allowing us to identify their common frustrations and challenges, as well as their particular expectations. This user-centered approach for both groups enabled us to balance EstApp's features to cater to both, creating a platform that is useful for both teaching and learning.
Prototype validation	The design process for EstApp required significant time and resources, especially in creating and validating the wireframes.	We employed an "incremental design" strategy, starting with low-fidelity wireframes to gather quick and cost-effective feedback before moving on to medium- and high-fidelity versions. This approach allowed us to iterate quickly without overburdening the project.
Personalized education	Not all team members were experts or professors in the field of statistics, so the rest of the team had to learn key concepts to properly design EstApp in a way that was intuitive and facilitated the understanding of complex concepts.	We held various team meetings to learn and familiarize ourselves with statistical concepts. These meetings included internal validations of the most important features, the wireframes, and how to make the interaction "logical" from a statistical perspective. Additionally, we conducted usability tests with students to ensure that the designs were intuitive for them. This allowed us to adjust the design to ensure students clearly understood the content.

#### 6.4. Limitations and Opportunities for Improvement

Although we conducted 14 interviews, surveyed 440 students, and performed a user test with 17 students to validate EstApp, the sample was limited to the university context of the Pontificia Universidad Católica de Valparaíso, Chile. This may limit the generalizability of the results to other university environments or to students with different cultural and educational backgrounds. However, as the first version of EstApp, we consider that we have achieved good results, and its functionalities could be applicable in other contexts. With respect to functionalities, we prioritized the “Probability Calculator”, “Data Generator”, “Data Visualizer”, “AI Tutor”, and “Report Generation” as the most valuable features for students and professors. However, key functionalities such as advanced data manipulation or statistical inference analysis may not have been considered. This could limit the use of EstApp for more advanced topics within statistics courses. On the other hand, while we conducted usability/UX tests, these were limited to a prototype version of EstApp. We have yet to test it in a long-term educational setting, which may reveal other challenges or areas for improvement when used continuously.

For a future version of EstApp, it would be useful to conduct studies in different academic contexts, including universities in other countries and regions (and in languages other than Spanish), to validate the application’s usefulness for a broader audience. The user sample could also be expanded to include individuals with varying levels of statistical expertise, including students from different disciplines.

Additionally, future versions could incorporate advanced functionalities, such as inferential statistical analysis, linear regression, and tools for working with large datasets. These improvements would extend the application’s use to more advanced statistics courses. Another opportunity for improvement would be to integrate EstApp with learning management systems (LMS, such as Moodle [47]), allowing professors to manage student progress centrally.

Finally, it is crucial to conduct studies in real educational settings, testing the application’s effectiveness over several semesters. This would allow for observations of how the app impacts student learning and motivation in the long term and identify potential issues or areas of improvement not discovered during the initial usability tests. Specifically, to evaluate the long-term effects of EstApp on academic performance and motivation, it is essential to collect and analyze empirical data to support its effectiveness. One approach could be to define control groups (who do not use EstApp) and experimental groups (who use the new application) within a course, and track over time how the application influences knowledge retention, statistical reasoning, performance, and motivation. Pre- and post-assessments could be conducted using questionnaires to evaluate technology acceptance (TAM [48]) or scales to measure motivation [49], assessing factors such as intrinsic motivation, extrinsic motivation, and amotivation. Additionally, by comparing these results with those obtained by users of other applications, we could strengthen the argument that EstApp not only improves the learning of statistical concepts but also offers a more personalized and tailored experience to meet students’ individual needs.

## 7. Conclusions and Future Work

A user-centered approach guided the development of the “EstApp” application. This approach, which involved students and professors in all stages of the design, from the Empathize to the Test phase, has been instrumental in creating an educational tool that not only meets the technical needs of teaching statistics but also enhances students’ learning experiences. This should bring reassurance about the effectiveness of “EstApp” in the educational context.

The results obtained from the user tests highlight the intuitiveness and usefulness of “EstApp”, especially in functionalities such as the Data Generator and the Data Visualizer, where 94.1% of users indicated that the application was easy or very easy to use and all of them found the functionalities of the application very useful (see Section 4.5). However, areas for improvement were identified, mainly in aspects related to the user interface

and the presentation of results (29.4% of participants suggested improvements in visual presentation, such as changing the color palette, improving typography, and adding more visual elements, see Section 4.5), which underlines the importance of continuous feedback from users to iterate on the application's design. In comparative terms, our current solution is favorably positioned against other educational tools by offering a unique combination of interactive simulations, advanced data visualization, and an artificial intelligence-based tutor, contributing to deeper and more personalized statistics learning.

Future development of "EstApp" will incorporate user-suggested enhancements, such as optimizing the color palette and expanding the available functionalities, including adding new chart types and analysis tools. In addition, integrating emerging technologies, such as augmented reality, will be explored to enrich the educational experience and facilitate understanding of complex statistical concepts. Another line of future work includes expanding the use of "EstApp" to other educational contexts, such as secondary education and vocational training programs, adapting the interface and functionalities to meet the specific needs of these new users. It is also proposed that longitudinal studies be conducted to assess the long-term impact of "EstApp" on students' academic performances and motivation. Finally, integrating "EstApp" with existing learning management systems (LMS) is considered relevant (such as Moodle [47] and Google Classroom [50], among others). This would allow educators to easily incorporate the tool into their courses and track students' progress in more detail. This step would open new opportunities for learning personalization and real-time content adaptation, maximizing the educational impact of the application.

**Author Contributions:** Conceptualization, D.Q. and F.R.; methodology, D.Q.; software, D.Q., F.R., J.O. and L.F.R.; validation, D.Q., L.F.R. and J.O.; formal analysis, D.Q. and J.O.; investigation, D.Q., F.R., J.D.-A. and F.P.; resources, D.Q. and F.R.; data curation, D.Q. and J.O.; writing—original draft preparation, D.Q., J.D.-A., F.P., J.O. and L.F.R.; writing—review and editing, D.Q.; visualization, D.Q.; supervision, D.Q.; project administration, D.Q. and F.R.; funding acquisition, D.Q., F.R., J.D.-A. and L.F.R. All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted in accordance with the ethical standards defined in the regulations of the Pontificia Universidad Católica de Valparaíso, Chile (protocol code BIOEPUCV-H 779-2024, date of approval: 4 June 2024), the Declaration of Bioethics and Human Rights of 2005 by UNESCO, and the ANID regulations for studies involving humans.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

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## Appendix A. Empathize Phase—Interview

Table A1. Empathize phase: interview questions.

User Profile	Background Questions	“About Experience” Questions
Students	<ul style="list-style-type: none"> <li>■ How old are you?</li> <li>■ Could you indicate your gender? (If you prefer not to say, that’s fine)</li> <li>■ In which city do you live?</li> <li>■ What major are you studying? What year are you in?</li> </ul>	<ul style="list-style-type: none"> <li>■ Do you like statistics in general? Why?</li> <li>■ What statistics courses are you currently taking or have taken at the university? How was your experience and how did you feel?</li> <li>■ What types of activities or teaching approaches are most effective for you in understanding descriptive statistics concepts?</li> <li>■ What kind of resources or tools do you use or have used to study descriptive statistics?</li> <li>■ What are the main challenges or difficulties you face when learning descriptive statistics?</li> <li>■ Is there something that motivates you when learning descriptive statistics in the classroom? What is it?</li> <li>■ Do you know or have you used any mobile or web applications oriented towards learning? Which ones? (If you don’t know any, don’t worry, we will give you examples)</li> <li>■ Do you think a (mobile or web) application would be useful to support learning during the statistics class? Why?</li> <li>■ What would you like this application to have or do?</li> <li>■ If this (mobile or web) application had options to study outside of class, would you use it? Why? What material would you like to see?</li> </ul>
Professors	<ul style="list-style-type: none"> <li>■ How old are you?</li> <li>■ Could you indicate your gender? (If you prefer not to say, that’s fine)</li> <li>■ In which city do you live?</li> <li>■ Which major(s) do you teach? Which academic unit do you belong to?</li> </ul>	<ul style="list-style-type: none"> <li>■ How long have you been teaching statistics at the university? How has your experience been?</li> <li>■ What do you like most about teaching statistics?</li> <li>■ What do you like least about teaching statistics?</li> <li>■ What are the biggest challenges or difficulties you face when teaching descriptive statistics in the university classroom?</li> <li>■ Usually, what is the methodology and/or organization of your classes like? For example, if you have to teach measures of central tendency, how do you organize the session?</li> <li>■ Usually, how is the participation of students in your classes? How does it make you feel as a teacher?</li> <li>■ Do you know or have you used any mobile or web applications oriented towards learning? Which ones? (If you don’t know any, don’t worry, we will give you examples)</li> <li>■ Do you think a (mobile or web) application would be useful to support learning during the statistics class? Why?</li> <li>■ If the answer to the previous question was yes, what would you like this application to have or do?</li> <li>■ Would you use an application to provide support material to your students outside of class hours? What type of material do you consider appropriate?</li> </ul>

### Appendix B. Ideation Phase—Brainstorming

FUNCTIONALITIES							FREE VERSION	LIGHT PAID VERSION	PREMIUM PAID VERSION	
<b>COLLECT DATA IN A GAMIFIED WAY</b>	Games of chances	Toss of a coin	Spin roulettes	Snake	Draw cards		Only 1 type	3 different types	More than 5 types	
<b>COLLECT DATA THROUGH SURVEYS AND QUESTIONS</b>	Multiple choice questions	Open questions	True or false	Ranking	Word cloud	Scales	2 different questions	4 different questions	More than 6 different questions	
<b>DATA VIEWER</b>	Bar Charts	Line charts	Pie Charts	Histograms	Scatter plots	Box plots	Charts for distributions	See maximum 2 simultaneous variables	See maximum 3 simultaneous variables	See maximum 5 simultaneous variables
<b>INCLUDE INTELLIGENT TUTOR (AI)</b>	Ask questions to understand types of statistical data	Upload document in PDF format	Analyze documents to ask about the content					5 free daily questions	10 free daily questions	Unlimited daily questions
<b>BULK LOAD DATA</b>	Upload course student lists	Upload data to analyze variables						Not available	Files up to 1 MB	Files up to 50 MB
<b>GENERATE REPORTS</b>	Student performance	Application usage	Satisfaction level with the exercises	Satisfaction level with the activities	Satisfaction level with the classes			Not available	Only student performance reports	Unlimited reports
<b>PREDICT STUDENTS AT ACADEMIC RISK</b>	Notify about students who do not participate in activities	Notify about students who repeatedly answer incorrectly						Not available	Not available	Available
<b>DELIVER FEEDBACK TO THE STUDENT</b>	Show the exercise result	Show the exercise solution process						Only shows the exercise result	Shows the procedure and the exercise result	Shows the procedure with detailed explanations and the result
<b>INCLUDE EXERCISES FOR SELF-STUDY</b>	Generate practice exercises	Show the exercise result						Available	Available	Available
<b>INCLUDE SECTION WITH STATISTICAL CONCEPTS</b>	Show concepts descriptions	Provide usage examples	Provide references for further information					Available	Available	Available
<b>INCLUDE SECTION WITH STATISTICAL FORMULAS</b>	Display formulas	Show which variables are used	Show a brief description of each variable					Includes only statistical formulas	Includes only statistical formulas	Includes statistical formulas and a detailed explanation of each one
<b>CUSTOMIZE A COURSE</b>	Change the course name	Change the course cover page	Add the course syllabus					Only the course name can be changed	The course name can be changed, and the syllabus and image can be added.	Everything is customizable
<b>CREATE COORDINATED COURSE</b>	Edit quizzes collaboratively	Upload data for use across parallel classes	Use course features collaboratively					Not available	Not available	Unlimited collaborators

Figure A1. Ideation phase: brainstorming results (functionalities).

### Appendix C. Ideation Phase—Information Architecture

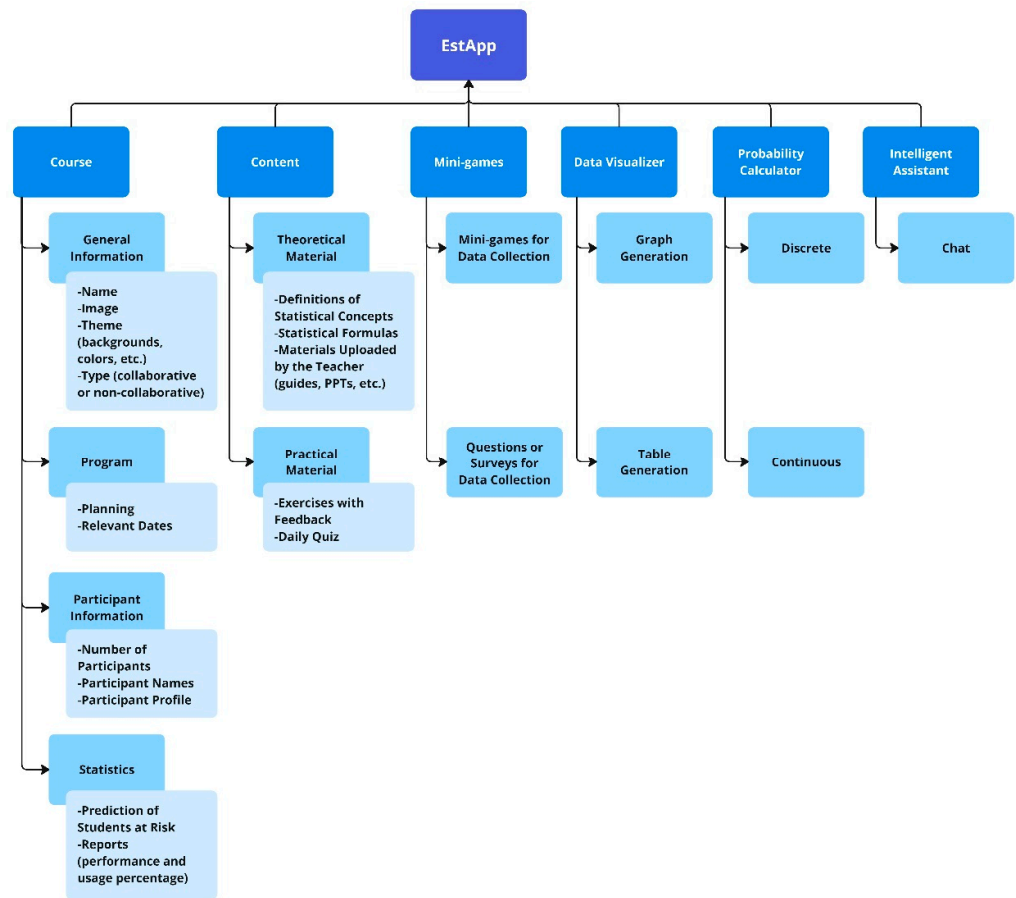


Figure A2. Ideation phase: information architecture for EstApp.

### Appendix D. Test Phase—User Testing Scenarios

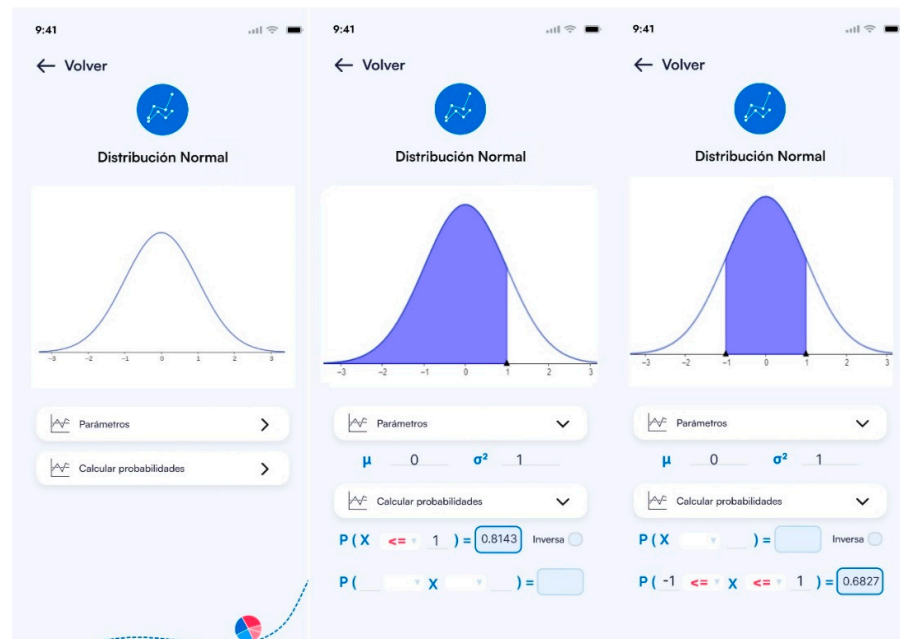


Figure A3. User test. Scenario 1: Probability Calculator.

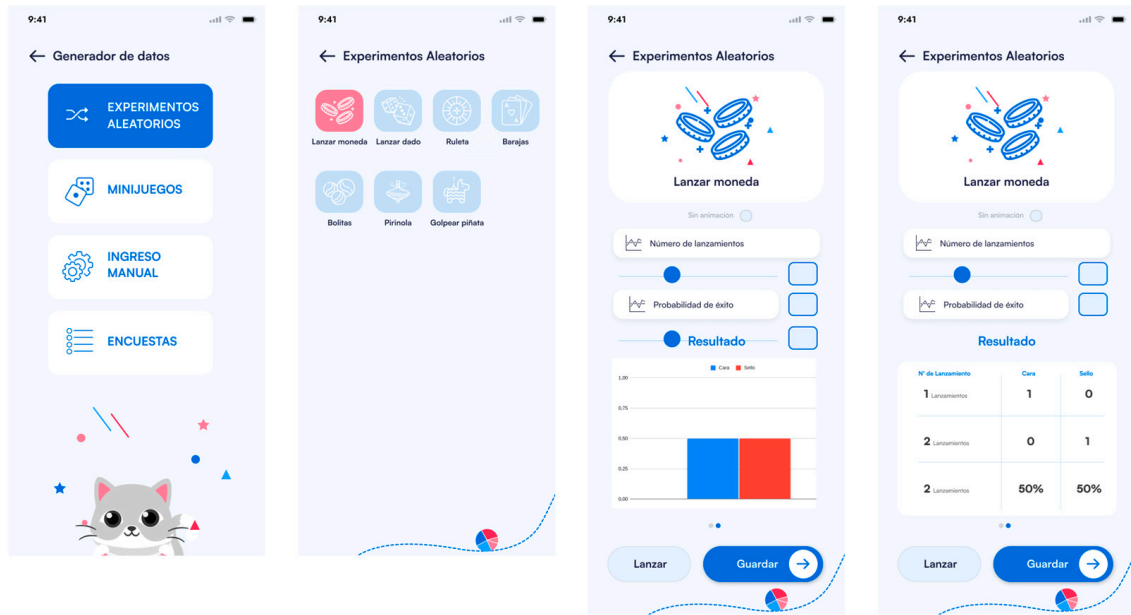


Figure A4. User test. Scenario 2: Data Generator.

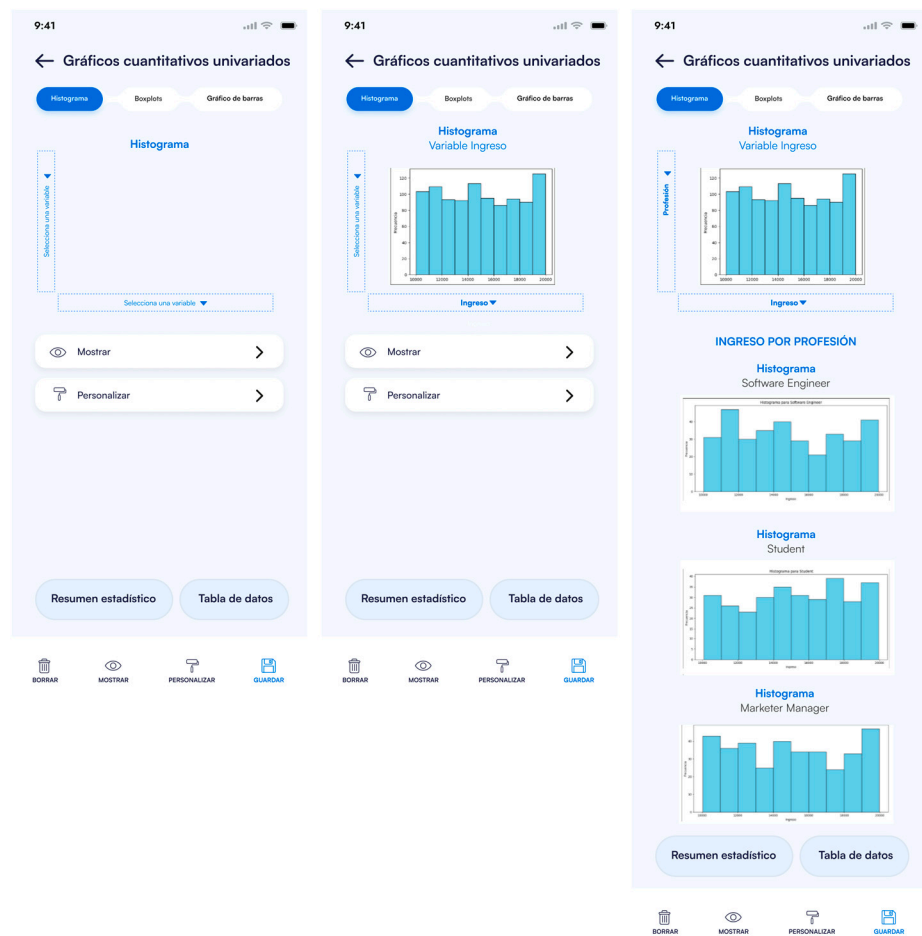


Figure A5. User test. Scenario 3: Data Visualizer: Histogram.

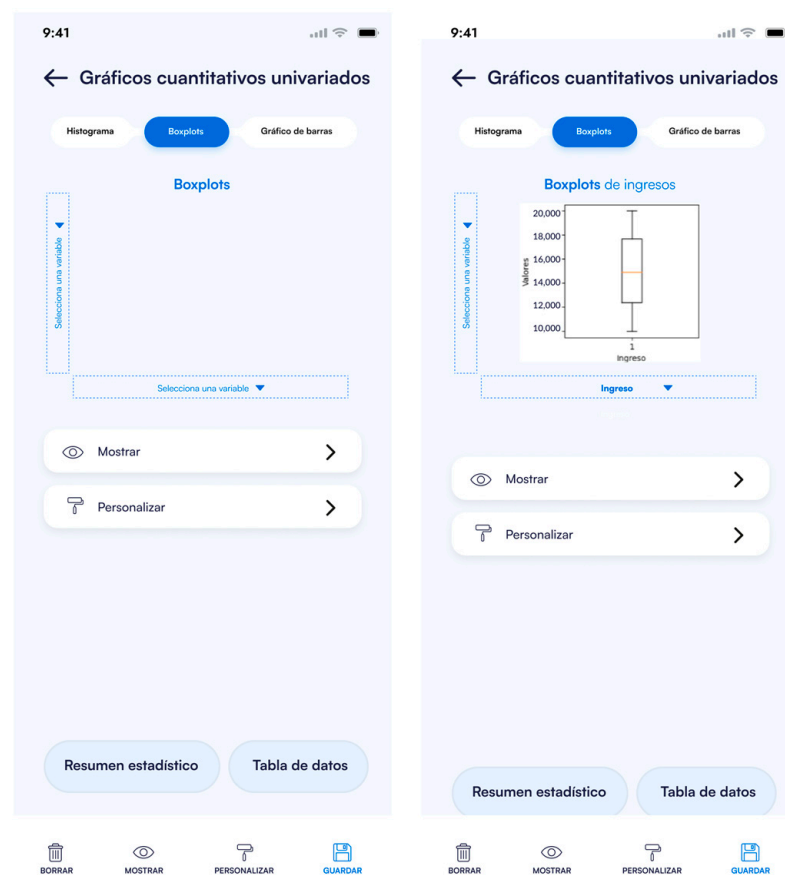


Figure A6. User test. Scenario 4: Data Visualizer: Boxplot.

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