Calculator-Based Emulator to Enhance Statistics Teaching: A University Case Study

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Abstract

Statistical competence is fundamental in various fields, but many students and researchers have difficulties in effectively applying statistical concepts. This study aims to evaluate and measure the impact of the integration of the CASIO fx-570 emulator calculator in the teaching of statistics at the university level with a sample of 170 university students, which was divided into two groups (control and experimental) and was where the CASIO fx-570 emulator was used in order to integrate theory with practice and foster a more intuitive and engaging learning experience. Pre- and post-tests assessed the effect of the intervention on conceptual, procedural and attitudinal learning dimensions. Mann-Whitney U tests revealed statistically significant improvements ($p < 0.05$) in all dimensions for the experimental group. These results demonstrate the potential of the CASIO fx-570 emulator to improve the learning of statistics in university students. In conclusion, it is necessary to take into account current educational needs and take advantage of technological advances to bridge the gap between statistical theory and practice, as well as to foster a more intuitive understanding of statistics in research.

Keywords: Education, Statistical Literacy, CASIO Fx-570 Emulator, University Students.

1 Introduction

The use of technological tools is booming exponentially, even more if they are applied to education, in sectors such as science and especially mathematics is of utmost importance and in statistics the calculator is very important at the beginning because it is very significant the use of these (Garcia-Lázaro et al., 2024). And like mathematics, statistics is a fundamental tool in the fields of education, economics, administration and demography. Through rigorous organization, critical analysis and systematic interpretation of data, statistics facilitates making the best informed decisions and ensures the reliability and validity of research results, this because it guarantees the credibility of a study and draws from it clear and concise conclusions, it is essential to select the appropriate statistical analysis techniques (Jacho et al., 2020). In the fields of pedagogy and research, the importance of statistical methods is essential, as they allow us to understand the variability of events, statistical-

mathematical techniques are of great importance in the educational research sector for the processing, analysis and interpretation of data (Cardoso et al., 2022). Unfortunately, a notable challenge in this field is the perception and complexity of statistical concepts, which many master's students in education find difficult; this difficulty sometimes leads educators to direct qualitative research to the detriment of statistical analysis (Ramón & Vílchez, 2020).

Educators' preference for qualitative research is not based solely on scientific grounds. However, some authors argue that while it is possible to conduct scientific research without resorting to statistics, this undoubtedly improves the reliability as well as the scientific rigor of the data (Henrique-Hevia &Peña-Alvarez, 2020). Despite the acknowledged importance of statistics, discrepancies often arise in study design, data analysis, and interpretation of results (Gamboa, 2018). This suggests the utmost importance of deepening and investigating the knowledge and its applications of statistical methods, especially in educational settings where data analysis can significantly influence educational strategies and outcomes that are products of the use of ICT and digital competencies (Faustino & Pérez, 2013). Deficiencies in the understanding of statistics may be due to inadequate statistical education, which leads to underdevelopment of scientific reasoning skills and hinders the understanding of statistical methodologies (HuamánRomaní et al., 2023). Thus, the essential role of applied statistics in demonstrating and ensuring objectivity in educational research is highlighted (Torres, 2020). However, a major obstacle lies in the persistence of traditional educational models that focus and prioritize calculation and rote analysis over critical statistical thinking (Ribeiro, 2016), this deficiency is aggravated by the lack of teachers' competence in effective pedagogical models, strategies and tools for teaching statistics (Ramos, 2019). Furthermore, Ramon and Vilchez (2020) note that even when a variety of teaching methods are used, they often remain outdated and do not address or take into account the changing needs of the learner, but at the heart of these needs is the integration of digital technologies as tools and resources for processing information, a critical aspect of modern education that enhances both engagement and understanding (Ramos, 2019).

In the last decade, the field of statistics has evolved significantly, creating new challenges for statistical education at the university level, especially in the statistical training of researchers (Blanco, 2018). This evolution requires prioritizing conceptual-interpretative, contextualprocedural knowledge, technological integration, as well as critical thinking skills (Cardoso et al., 2022). This approach will also necessitate the development of conceptual insights and argumentative skills that go beyond computational and repetitive tasks (Tortoriello & Veronesi, 2022). In response to these educational demands, the adoption of innovative technologies and pedagogical models has become fundamental. Among them, the flipped classroom model stands out for the effective use of technology inside and outside the classroom to organize and execute different school activities (Salas-Rueda, 2022).

The integration of graphing calculators and other technological tools into the curriculum offers a powerful advantage, as it facilitates a multidimensional exploration of mathematical and statistical concepts and allows students to approach these topics from various perspectives: numerical, analytical, and graphical. This holistic approach not only develops the learning experience and also better prepares students for the complex challenges of modern statistical research (Tortoriello & Veronesi, 2022).

2 Literature Review

The curricula of many Peruvian universities include courses in Statistics Applied to Research, offered in the fifth cycle of studies. To explore and evaluate the current status of the curriculum, a survey of ten professors who have taught this subject was conducted. The survey revealed several key points such as:

- Gaps in basic knowledge: 40% of the teacher’s state that students have difficulties with the subject of statistics due to a lack of some prior knowledge (“students fail to learn the subject due to the limited knowledge they come with from secondary school”).

- Lack of didactic material: 21.5% of the respondents noted a lack of well-prepared didactic material to support students' learning ("teachers do not have prepared didactic material").
- Difficulties with conceptual knowledge: 45% of respondents identified difficulties in assimilating pedagogical knowledge ("it is not easy to learn conceptual knowledge").
- Difficulties with procedural knowledge: 60 % of the respondents identified difficulties in the ability of the students themselves to be able to apply all their procedural knowledge to solve all practical problems ("procedural knowledge is difficult or very difficult to solve didactic situations").
- Perception of lack of commitment: "35% of the respondents consider that the subject is perceived as boring by the students, which leads to limited participation (" the subject is tedious, and they participate because the teacher forces them to do it, without them taking the initiative").

These results show the importance of a multifaceted approach to teaching and learning that encompasses procedural, attitudinal, and conceptual dimensions. Peña-Troncoso et al., (2023) advocate educational strategies that address these three dimensions simultaneously to support the understanding and application of statistical concepts. Based on Córdova (2012), this approach involves the development of a) conceptual knowledge (i.e., the acquisition of knowledge about principles, facts, and the set of declarative information to remember and memorize); b) procedural knowledge (i.e., the processes and actions necessary to achieve a goal; the dynamic dimension of learning); and c) attitudinal development (i.e., the cultivation of values and social norms that regulate behavior and attitudes). The integration of ICT in the education sector offers a promising approach to bridge these dimensions, providing opportunities for students to apply statistics to real-world problems and scenarios, thus enhancing their academic training (Morales et al., 2015). Although the technology has potential, integrating it into pedagogy is no easy task. Moreover, at a slow rate of adoption, proper incorporation of technology-based learning tools also requires a shift in teaching paradigms, which are often based on previous teaching experiences, lack of specific training, and sometimes resilience or interest in fully adopting technology-based learning tools (Pérez & Rodriguez, 2022). A relevant example of technology used for the teaching-learning of statistics is the use of calculators, which have evolved significantly, offering sophisticated functionalities that were previously unavailable. Despite these advances, the high cost of advanced calculators can limit student access, however, emulator software represents a viable solution to this problem (Hernández et al., 2022). An emulator is an information system that reproduces the functions of a device on a different medium (CASIO s.f), eliminating the need for additional physical devices. For example, the software of a calculator can be adapted for use on a computer, without the need to purchase the calculator. This alternative allows the teacher to offer advanced and realistic computational tools and methods at a lower cost (Ritzel et al., 2018).

2.1 Justification and Objective

The information described above exposes deficiencies and problems in the teaching and learning of statistics in university students, particularly in the university where this study was conducted, which is the National University of Education "Enrique Guzmán y Valle". This research aims to evaluate and measure the effects of the CASIO fx-570 scientific calculator emulator, and if it can significantly improve the conceptual, procedural and attitudinal aspects in the learning of statistics applied to research in fifth cycle students of this university, since there are still the effects of the arrival of COVID-19, which was an abrupt transition from face-to-face teaching to e-learning, and the subsequent return to face-to-face classes, both students and teachers were forced to develop digital skills and competencies for the development of academic sessions, which also led to the development of collaborative

attitudes. Another objective of this research work is also to analyse the correlation between the development of digital competencies and collaborative attitudes in university students. In addition, to give more emphasis to the research, we will have the following specific objectives: a) To determine and analyse the digital competences of university students and their dimensions (digital competences of search and information processing and interpersonal competences in the use of the university ICT environment) and b). Determine and analyse the collaborative attitudes of university students.

3 Methodology

This study employed a quantitative, quasi-experimental research approach to evaluate the impact of the CASIO fx-570 scientific calculator emulator on statistics learning. According to Hernández-Sampieri and Mendoza (2018), a quantitative approach involves following a sequence of structured procedures to test various hypotheses. Furthermore, Hernández-Sampieri and Mendoza (2018) emphasize that no step in any of the phases should be omitted, although it is possible to redefine some at another stage. This research is aligned with what Piscoya (1995) categorized as a social technologies research and follows a hypothetical-deductive methodology which is a method that starts from hypothetical propositions and aims to disprove or modify them through empirical evidence, leading to conclusions that must be proven through facts (Bernal, 2016).

3.1 Population and Sample

The research involved 170 fifth cycle students of the National University of Education (UNE), all of whom gave their informed consent. The sampling method was census and to test the hypothesis, the participants were divided into two groups, one control and one experimental, according to the pre-existing academic performance of the academic records held by the teachers in charge of the courses. The control group consisted of students with high grades and the experimental group consisted of students with low grades. Both groups were defined beforehand, and both received pre and post evaluations, through a survey, before and after the exposure to the course in specific topics of Statistics.

For this reason, the following evaluation tools were developed:

Intervention material using the CASIO fx-570 scientific calculator emulator for each class session.

A 10-item multiple-choice instrument to measure conceptual learning.

A 10-item multiple-choice instrument to measure procedural learning.

A 10-item Likert-type instrument to measure attitudinal learning.

The multiple-choice instruments used a four-alternative format, while the attitudinal instrument used a three-alternative format. After the application of the research instruments, a descriptive statistical analysis was performed. The results were classified into four levels: High (7.5 - 10), Fair (5 - 7.5), Low (2.5 - 5) and Very low (0 - 2.5). To ensure content validity, the instruments were reviewed by three subject matter experts, who obtained validity scores of 86.00%, 89.33% and 91.00% for the conceptual, procedural and attitudinal assessments, respectively. The average validity of the instruments was 88.77%, indicating a very good level of validity. To evaluate the reliability of the instruments, the KR20 statistic or Kuder-Richardson formula 20 was used, which yielded a value of 0.757, indicating that the instruments are acceptably reliable and can be applied for the research.

3.2 Instrument

To evaluate the distribution of learning achievements in conceptual and procedural knowledge of statistics applied to research, a normality analysis of the scores obtained after the test by 170 students was performed. The results are presented in Table 1.

	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistician	gl	Sig.	Statistician	gl	Sig.

Conceptual_Control_Post	0,159	70	0,000	0,939	70	0,002
Procedural_Control_Post	0,240	70	0,000	0,888	70	0,000
Attitudinal_Control_Post	0,143	70	0,001	0,940	70	0,002
Conceptual_Experim_Post	0,196	70	0,000	0,918	70	0,000
Procedural_Experim_Post	0,139	70	0,002	0,953	70	0,011
Attitudinal_Experim_Post	0,191	70	0,000	0,902	70	0,000

Table 1. Normality of the Data

a. Lilliefors significance correction

The results of the Kolmogorov-Smirnov and Shapiro-Wilk tests indicate significant deviations from normality in all groups and types of knowledge. Since the significance values for all variables were less than 0.05, the null hypothesis of normality was rejected. Therefore, nonparametric hypothesis testing was considered appropriate, and the Mann-Whitney U test for independent groups was used.

4 Results

Table 2 presents the results, in percentages, of the levels of achievement of conceptual knowledge, both in the pre-tests and in the post-tests, in which the university students participated.

		Pre-test		Post-test	
		Control G	Exp. G	Control G	Exp. G
Level	Range	% Frequency	% Frequency	% Frequency	% Frequency
High	[7.5, 10]	0.00	0.00	24.00	45.71
Regular	[5, 7.5[	16.00	8.57	50.00	50.00
Low	[2.5, 5[	72.00	70.00	21.00	4.29
Very low	[0, 2.5[	12.00	21.43	5.00	0.00
		100.00	100.00	100.00	100.00

Table 2.

Achievement levels and pre-test and post-test percentages of conceptual knowledge in the control and experimental groups.

The Post-test results show significant improvements in the conceptual understanding of the applied research statistics course within the experimental group compared to the control group.

In particular, all students in the experimental group surpassed the “Very Low” knowledge level, and only a small fraction of 4.29 % remained in the “Low” category. In contrast, the control group achieved 7.14 % the “Very Low” level, 27 % the “Low” level, 40 % the “Fair” level and 25.71 % the “High” level. In addition, the experimental group achieved 44.29% the “High” level and 51.43% achieved the “Regular” level and the control group obtained 40% the “Regular” level; which indicates that probably these results improve the conceptual learning in the experimental group so it is recommended the use of the CASIO fx-570 simulator in the development of the classes of statistics applied to research with university students.

Table 3 presents the results, in percentages, of the achievement levels of the procedural knowledge, both in the pre-test and post-test.

	Pre-test		Post-test	
	Control G	Exp. G	Control G	Exp. G

Level	Range	% Frequency	% Frequency	% Frequency	% Frequency
High	[7.5, 10]	0,00	0,00	32,86	22,86
Regular	[5, 7.5[	10,00	4,29	45,71	55,71
Low	[2.5, 5[	72,86	64,29	20,00	17,14
Very low	[0, 2.5[	17,14	31,43	1,43	1,25
		100.00	100.00	100.00	100.00

Table 3.

Achievement levels and pre-test and post-test percentages of procedural knowledge in the control and experimental groups.

The Post-test results show a significant improvement in the procedural understanding of the applied research statistics course within the experimental group, compared to the control group.

In particular, all students in the experimental group surpassed the “Very Low” knowledge level, and only a small fraction of 17.14% remained in the “Low” category. In contrast, the control group achieved 1.43% the “Very Low” level, 20% the “Low” level, 45.71% the “Fair” level and 32.86% the “High” level. In addition, 22.86% of the experimental group achieved the “High” level and 55.71% achieved the “Regular” level, which indicates that there are positive and significant results from the use of the CASIO fx-570 simulator in class.

To statistically examine these differences in conceptual, procedural and attitudinal knowledge, a Mann-Whitney U test was performed. The test findings are summarized in Tables 4, 5 and 6.

Table 4. Presents the results, in percentages, of the attainment levels of attitudinal knowledge in both the pre-test and post-test in the applied statistics research students.

		Pre-test		Post-test	
		Control G	Exp. G	Control G	Exp. G
Level	Range	% Frequency	% Frequency	% Frequency	% Frequency
High	[7.5, 10]	0,00	0,00	18,57	32,86
Regular	[5, 7.5[	20,00	8,57	60,00	55,71
Low	[2.5, 5[	67,14	67,14	14,29	7,14
Very low	[0, 2.5[	12,86	24,29	7,14	4,29
		100.00	100.00	100.00	100.00

Table 4.

Attainment levels and pre-test and post-test percentages of attitudinal knowledge in the control and experimental groups.

Post-test results show a significant improvement in the attitudinal understanding of students within the experimental group, compared to the control group (Table 4). In particular, all students in the experimental group surpassed the “Very Low” knowledge level, and only a small fraction of 7.14% remained in the “Low” category. In contrast, the control group achieved 7.14% the “Very Low” level, 14.29% the “Low” level, 60% the “Fair” level and 18.57% the “High” level. In addition, the experimental group achieved 55.71% the “Regular” level and 32.86% achieved the “High” level; indicating that these results of significant improvement are probably due to the use of the CASIO fx simulator in class. To statistically examine these differences in conceptual and procedural knowledge, a Mann-Whitney U test was performed.

Evaluation of the Improvement of Conceptual Learning.

As a null hypothesis, Together's distribution will be considered to evaluate if the level of procedural learning is the same between group categories. Where the significance level is 0.000 with the Mann Whitney U test, with which the decision is made to reject the null hypothesis. The Mann-Whitney U test obtained an asymptotic (bilateral) significance level of 0.000, which is below the conventional threshold of 0.05, indicating a significant difference between the groups. This result led us to reject the null hypothesis, thus affirming that the intervention, specifically the use of the CASIO fx-570 scientific calculator emulator, has a positive and significant effect on the conceptual learning of statistics applied to research among fifth-cycle university students.

4.1 Assessment of Procedural Learning Improvement

As a null hypothesis, Together's distribution will be considered to evaluate if the level of procedural learning is the same between group categories. Where the significance level is 0.000 with the Mann Whitney U test, with which the decision is made to reject the null hypothesis. Similarly, the Mann-Whitney U test indicated an asymptotic (bilateral) significance level of 0.000. This value is lower than the conventional significance level of 0.05. Consequently, we rejected the null hypothesis, concluding that the didactic material using the CASIO fx-570 scientific calculator emulator significantly improved the procedural learning of statistics applied to research among fifth cycle university students.

4.2 Evaluation of the Improvement of Attitudinal Learning

As a null hypothesis, Together's distribution will be considered to evaluate whether the level of attitudinal learning is the same between group categories. Where the significance level is 0.000 with the Mann Whitney U test, with which the decision is made to reject the null hypothesis. The Mann-Whitney U test indicated an asymptotic significance level (bilateral) of 0.000. This result ($p < 0.05$) indicates the rejection of the null hypothesis, supporting the conclusion that the didactic material used from the CASIO fx-570 scientific calculator emulator did improve attitudinal learning in fifth cycle university students.

5 Discussion

This study demonstrates the positive impact of the CASIO fx-570 scientific calculator emulator on the three learning dimensions analysed. The significant progress of the experimental group in the conceptual understanding of statistics applied to research suggests that the intervention effectively facilitated their learning process. This finding coincides with that of Faustino and Perez (2013), who proved that the statistical software tool, created using IBM SPSS V.20, similarly improved the learning outcomes achieved. Their study employed Pearson's correlation coefficient, Chi-square test of independence (34.489) and Kendall's W (0.192), concluding an efficacy level of 95.5% for the promotion of investigative thinking and the effectiveness of innovative interventions in the learning process.

These convergent results highlight the value and potential of learning interventions enabled by the use of technology in the classroom that develops the topic of statistics applied to research. The results further contribute to the college student learning set and suggest that innovative educational interventions can significantly influence college students' teaching-learning processes and the development of their critical thinking skills (Huamán-Romaní et al., 2022a).

Furthermore, our results in relation to conceptual, procedural and attitudinal learning support the findings of Metaute, et al. (2018), who demonstrated that a blended approach using an inverted classroom and traditional pedagogy, the former improves the results in the learning cases of the subjects studied and the study presented improved the understanding of statistics applied to research by increasing the percentage of correct answers in the tests applied. Their success rates (83.5% - 93%) in the conceptual, procedural and attitudinal assessments highlight the potential of innovative pedagogical approaches. Interestingly, their results showed lower success (38%45%) in argumentative learning, potentially due to the

learner-cantered nature of the flipped classroom, which places greater responsibility on the learner. This suggests the need for careful technology tool use classroom support and scaffolding when students are expected to perform in learner-cantered environments (Sarmiento-Campos et al., 2022).

When evaluating the effectiveness of innovative teaching interventions, it is essential to consider factors beyond the intervention itself. These include the complexity of innovative interventions, the ease of implementation by the teacher, and the degree of control that the teacher maintains over the entire learning process. These elements not only affect the direct outcomes of educational interventions, but also influence the extent to which learners engage with and benefit from these innovative approaches (Alstete et al., 2024). It has also been shown that the less control is exerted over the intervention, the more the outcomes depend on learner participation and engagement. This observation underscores the importance of designing educational interventions that not only facilitate learning through engagement, but also accommodate varying levels of teacher control and learner responsiveness.

Furthermore, our results support those of Segarra-Escandón (2023), who highlighted the role of the calculator in improving problem solving, concentration skills, and reducing computational errors. In addition, Jiang et al., (2023), observed that efficient calculator use is related to greater mathematical proficiency, and that students tend to use calculators for intensive and complex calculations.

Regarding attitudinal learning, previous studies have consistently shown that the application of innovative methods, strategies, and materials positively influence students' engagement, valuecreating, attendance, and interest in their studies. This was also found in research by Castillo (2020), whose mobile application designed to support the learning of inferential statistics at a Chilean university improved student evaluations, attitudes toward complex statistical concepts, and overall learning outcomes. The app included very trivial functions, a glossary, and an advisory mode for hypothesis testing with SPSS. These studies collectively suggest that the careful application of well-designed teaching methods, strategies, and materials can significantly influence students' attitudes toward learning.

From these results, we find two main challenges for educators and curriculum designers:

Accessibility and integration: innovative tools and methodologies should be designed in a way that ensures their accessibility and integration into existing educational frameworks, both for teachers and students, always integrating new information and communication technologies (Huamán-Romaní et al., 2022b).

Student participation and engagement: it is essential to cultivate an educational environment that supports and emphasizes student participation and engagement as crucial components of the learning experience. This involves designing interventions with student-cantered elements, providing support for self-regulated learning, and emphasizing the value of active participation (Maulana &Mariam, 2025).

By addressing these challenges, we can create more inclusive, adaptive, and effective learning environments, reinforced by the careful development and implementation of innovative technological interventions, such as the CASIO fx-570 scientific calculator emulator used in this study, that enhance the learning outcomes and experiences of undergraduate students in the fifthcycle applied statistics for research course. Beyond the immediate benefits observed in this study, our results suggest that technology has the potential to revolutionize and reshape teaching methodologies, fostering a shift toward more interactive, hands-on, and student-cantered learning experiences, so future research should investigate what these benefits will be.

5.1 Limitations of the Research

There was difficulty in gaining access to the calculators at the beginning, since the students only used simple calculators.

After performing and applying some calculations in practice, they were encouraged to make a guide on how to use the CASIO fx-570 calculator and publish it, but the respective authorization of the CASIO company was not obtained.

New experiences in university classrooms at the undergraduate or graduate level are always observed by the university authorities and are full of criticism from some of the colleagues of the same institution.

6 Conclusion

This study provides convincing evidence that the implementation of the CASIO fx-570 scientific calculator emulator as a teaching tool significantly improved conceptual, procedural, and attitudinal learning of statistics applied to research among undergraduate fifth-cycle university students.

The emulator's user-friendly interface and functions were particularly effective in demystifying complex concepts, enhancing procedural learning, and cultivating positive attitudes toward the study of statistics.

The results underscore the importance and potential of integrating innovative teaching materials into teaching practices to transform education. In addition, the reflective interventions also made the subject more accessible, thereby increasing students' confidence and motivation to engage in statistical analysis.

By positively influencing students' attitudes toward the study of statistics, the intervention not only provided short-term improvements, but also potentially laid the groundwork for the cultivation of a mindset more amenable to the fundamentals of research. Especially important given the crucial role of statistical literacy to the academic, professional, and social success of the practitioner.

The results are compelling in highlighting the importance of continued innovation in pedagogical approaches to ensure the successful acquisition of essential research skills among undergraduates.

Beyond the immediate benefits observed in this study, our results suggest that technology has the potential to revolutionize and reshape teaching methodologies, fostering a shift toward more interactive, hands-on, and student-cantered learning experiences.

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