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# Enhancing business students' data analytics skills through DataCamp mobile learning: A two-year quasi-experimental study

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## Abstract

This research evaluated DataCamp: Data Science & AI effectiveness in developing data analytics competencies among business administration undergraduates. Through a two-year quasi-experimental design, the study compared learning outcomes between 500 students using the mobile platform versus traditional instruction across three universities. Statistical analyses showed enhanced mobile learning performance ( $\beta = 0.86$ ,  $p = 0.041$ ). Growth Mixture Models identified three learning trajectories, with 45% displaying consistent improvement. The study measured competencies in data visualization, statistical analysis, and business applications. Regular platform interaction correlated with improved outcomes. Students valued accessibility but reported challenges with advanced concepts, highlighting implementation enhancement opportunities.

**Keywords:** data analytics education, mobile game-based learning, business statistics, educational technology, quantitative skills development

## Introduction

Business education faces persistent challenges in developing students' quantitative analysis skills, particularly in data interpretation and statistical reasoning. The increasing complexity of business analytics requires innovative approaches to prepare students for modern business environments. Mobile learning technologies offer potential solutions through accessible, engaging platforms that combine game mechanics with structured learning objectives.

DataCamp: Data Science & AI is an educational mobile application that focuses on data analysis and statistical concepts through practical business scenarios. The platform



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supports progressive skill development while maintaining accessibility through mobile devices. This study investigated how DataCamp influenced quantitative data interpretation skills among business administration students over a two-year period, comparing outcomes between mobile application users and those receiving traditional instruction.

The research examined the effectiveness of mobile game-based learning in business education by analyzing student performance data, engagement patterns, and learning outcomes. The investigation focused on competencies essential for modern business analysis, including data visualization interpretation, statistical concept application, and data-driven decision making. The study's longitudinal design enabled detailed analysis of how mobile learning tools influenced skill development over time.

This research contributes to understanding educational technology integration in business programs while maintaining focus on measurable learning outcomes. The findings provide evidence about effective teaching methods as programs adapt to changing industry needs. Through multiple analytical approaches including statistical analysis of performance data and engagement pattern examination, the study presents a comprehensive assessment of mobile learning effectiveness in business education contexts.

### **Literature review: Mobile game-based learning in business education**

The theoretical foundation of mobile game-based learning stemmed from constructivist learning theory and experiential learning models. Consequently, Lukosch and Cunningham (2018) established that interactive mobile applications facilitated active knowledge construction through hands-on experience with data analysis tasks.

Furthermore, Balayan et al. (2014) expanded this theoretical framework by incorporating elements of situated learning theory, suggesting that mobile educational games created authentic contexts for skill development. Additionally, their work highlighted how game mechanics could support the gradual building of complex analytical competencies. Moreover, the cognitive load theory informed the design of educational mobile games, as explored by Rasyid et al. (2020). Subsequently, their research indicated that well-designed mobile learning environments could reduce extraneous cognitive load while maintaining germane load essential for learning.

In addition, Oyelere et al. (2018) developed a theoretical model linking mobile learning engagement to skill acquisition in technical fields. Meanwhile, their framework emphasized the role of immediate feedback and progressive challenge levels in supporting sustained learning motivation. Nevertheless, Ribeiro et al. (2021) introduced spatial learning considerations to the theoretical discourse on mobile educational games. Therefore, their work suggested that location-aware features could enhance context-relevant learning experiences in business education settings.

Meanwhile, Demirbilek (2010) integrated adult learning theory with mobile game-based education principles. Subsequently, this integration highlighted the importance of self-directed learning opportunities and professional relevance in educational game design. The present study built upon these theoretical foundations while addressing specific gaps in understanding mobile game-based learning for business statistics education. Nonetheless, Ninghardjanti and Dirgatama (2021) noted limitations in existing research regarding long-term skill retention and transfer to professional contexts.

This research extended prior work by implementing a longitudinal design and focusing specifically on business data interpretation skills. Furthermore, the study's emphasis on practical application and skill transfer offered additional insights into the effectiveness of mobile learning tools in professional education. The literature review expanded into dimensions of adaptive learning and personalization in mobile educational contexts. Herodotou (2018) found that game mechanics supporting progressive skill development aligned with natural learning patterns. Meanwhile, Sandberg et al. (2014) documented how intelligent adaptation in mobile applications enhanced learning outcomes through personalized content delivery.

The meta-analytical work of Sung et al. (2016) synthesized evidence supporting mobile device integration in educational contexts. Subsequently, their findings highlighted factors influencing successful implementation, including structured learning pathways and clear pedagogical objectives. Additionally, Yadav and Oyelere (2021) addressed contextualization in mobile game-based learning, noting how domain-specific applications enhanced engagement and learning transfer. Furthermore, their work emphasized the importance of authentic business scenarios in educational game design.

Ng et al. (2020) explored user interaction patterns in educational mobile games, identifying elements that supported sustained engagement. Meanwhile, their research suggested that achievement systems aligned with learning objectives enhanced motivation without compromising educational value. The systematic review by Pedraja-Rejas et al. (2024) analyzed mobile learning's impact on critical thinking development. Consequently, their work highlighted how interactive elements in mobile applications supported higher-order cognitive skill development.

Pombo and Marques (2020) investigated how mobile learning environments could support practical skill application. Moreover, their findings suggested that well-designed mobile applications could bridge theoretical understanding and practical competency development. Recent meta-analytical work by Dong et al. (2024) quantified the effectiveness of mobile learning interventions across different educational contexts. Therefore, their findings supported the potential of mobile applications in developing technical and analytical skills.

This expanded theoretical framework strengthened the current study's approach to mobile game-based learning in business education. Additionally, it supported the research design's focus on long-term skill development and practical application of statistical concepts. The implementation of inquiry-based learning through mobile applications enhanced analytical skill development. Accordingly, Suárez et al. (2018) identified patterns in mobile learning activities that supported research skill development and data interpretation abilities.

Estrada Villa et al. (2021) expanded understanding of mobile learning in research training contexts. Subsequently, their work highlighted how mobile applications supported the development of information management competencies essential for business analysis. Moreover, Purwanti et al. (2019) analyzed engagement patterns in mobile learning environments. Meanwhile, their findings indicated that interactive elements and practical applications maintained student motivation throughout extended learning periods.

Tavares et al. (2021) focused on structured learning approaches in mobile educational applications. Furthermore, their research emphasized the importance of clear learning pathways and scaffolded skill development in technical education. Su and Cheng (2015) examined how gamification elements influenced learning motivation and achievement. Consequently, their work supported the integration of game mechanics with educational objectives to enhance learning outcomes.

Early meta-analytical work by Vogel et al. (2006) established foundational understanding of gaming in education. Additionally, their findings suggested lasting benefits of interactive learning environments for skill development. Yosiana et al. (2021) explored mobile learning effectiveness in quantitative skill development. Therefore, their research supported the application of mobile learning tools for developing statistical and mathematical competencies. This extended theoretical framework reinforced the current study's approach to mobile game-based learning while highlighting opportunities for future research in business education contexts. Nevertheless, questions remained about long-term retention and transfer of skills to professional settings.

The literature review supported the effectiveness of mobile game-based learning in developing quantitative skills while highlighting areas for continued investigation. The literature also expanded into regional contexts and specific applications in Colombian higher education. Accordingly, de la Puente Pacheco et al. (2025) analyzed technology-enhanced learning approaches in developing critical thinking skills. Meanwhile, their findings supported structured integration of digital tools in higher education. Lugo et al. (2024) explored mathematical skill development through digital platforms. Furthermore, their research emphasized the importance of systematic training approaches in quantitative education, particularly relevant to business statistics learning. De la Puente (2024) investigated educational gaming in local contexts, focusing on implementation strategies and learning outcomes. Subsequently, this work highlighted how cultural and institutional

factors influenced the effectiveness of game-based learning approaches. Also, De La Puente et al. (2024) conducted quasi-experimental research on online learning tools' impact on mathematical performance. Additionally, their methodology and findings supported the current study's approach to measuring educational technology effectiveness.

The work of Alberto de la Puente Pacheco et al. (2022) on critical thinking development through interactive learning strengthened the theoretical basis for game-based approaches. Moreover, their findings suggested that structured digital learning environments enhanced analytical skill development. Drawing from the theoretical foundations of constructivist learning theory, experiential learning models, and the empirical evidence on mobile game-based learning effectiveness, this study addresses specific research questions that emerge from gaps identified in the literature review.

RQ1: To what extent does the implementation of DataCamp: Data Science & AI mobile application enhance quantitative data interpretation skills among business administration undergraduate students compared to traditional instructional methods? This question directly addresses the need for empirical evidence on mobile learning effectiveness in business education contexts, as highlighted by Ninghardjanti and Dirgatama (2021) and supported by the theoretical frameworks of Lukosch and Cunningham (2018). RQ2: How do learning trajectories differ between students using mobile game-based learning versus traditional instruction across multiple semesters? RQ3: What relationship exists between student engagement patterns with the mobile platform and learning outcomes in data analytics competencies? RQ4: Do intervention effects vary across different student performance levels and learning profiles? These questions address the gaps in understanding long-term skill development and individual variation patterns identified in the literature synthesis.

H1: Students who use DataCamp: Data Science & AI mobile application will demonstrate significantly greater improvements in quantitative data interpretation skills compared to students receiving traditional instruction, as measured by standardized assessment scores over a two-year period. This hypothesis builds directly on the positive effects documented by Su and Cheng (2015) and the theoretical framework established by Balayan et al. (2014). H2: Students in the mobile game-based learning group will show accelerated skill development trajectories across semesters with larger effect sizes emerging over time. H3: Higher levels of engagement with the DataCamp platform will correlate positively with greater improvements in data analytics competencies. H4: Positive effects will remain consistent across different student performance quantiles. These predictions derive from the engagement patterns documented by Purwanti et al. (2019) and the theoretical models proposed by Oyelere et al. (2018).

## **International perspectives on mobile learning and game-based education: Western research developments**

Recent Western scholarship has significantly advanced understanding of mobile learning effectiveness in higher education contexts, providing critical theoretical frameworks that complement regional research findings. Eom (2023) conducted a comprehensive examination of mobile device usage impact on e-learning processes and perceived learning outcomes in university online education, establishing that mobile technologies serve as pivotal elements in student-centered educational ecosystems. His research suggested that mobile device integration enhances self-regulated learning capabilities and facilitates improved student-instructor dialogue, supporting theoretical frameworks that emphasize constructivist learning approaches in digital environments.

The practical application of mobile learning in specialized business education contexts has gained substantial attention in Western literature. Voshaar et al. (2022) investigated mobile application impact on learning success in accounting education, revealing significant improvements in student performance when mobile technologies were systematically integrated into curriculum delivery. Their findings indicated that mobile learning platforms enhanced engagement patterns and knowledge retention rates, particularly in quantitative analysis tasks requiring repeated practice and immediate feedback mechanisms. This research reinforced theoretical connections between mobile accessibility and sustained learning motivation documented in earlier constructivist learning models.

Institutional perspectives on mobile learning adoption have evolved considerably, as documented by Chen et al. (2023) in their longitudinal analysis of students' mobile learning practices in higher education. Their multi-year study revealed changing patterns in mobile device ownership, usage preferences, and learning application across diverse student populations in Western universities. The research highlighted how mobile learning practices adapt to institutional contexts while maintaining consistent effectiveness in supporting academic achievement, suggesting broad applicability of mobile learning interventions across different educational settings.

Systematic examination of game-based learning effectiveness has expanded through comprehensive Western literature reviews. Dahalan et al. (2024) conducted an extensive systematic literature review examining gamification and game-based learning applications in vocational education and training contexts. Their analysis synthesized evidence from multiple Western educational systems, demonstrating consistent positive effects of game-based approaches on student engagement, skill development, and learning outcomes. The review identified key implementation factors that influence game-based learning success, including structured progression systems, immediate feedback mechanisms, and integration with formal assessment procedures.

Educational psychology research provides foundational insights into mobile learning effectiveness. Mayer's (2019) multimedia learning principles demonstrate how mobile interfaces can optimize cognitive processing through dual-channel information presentation, while Sweller et al. (2019) extend cognitive load theory specifically to digital learning environments. From a global perspective, Crompton and Burke (2018) conducted a systematic review revealing that mobile learning effectiveness varies considerably depending on contextual factors such as cultural attitudes toward technology and collaborative learning practices. These interdisciplinary insights suggest that effective mobile learning design must consider cognitive and cultural dimensions beyond purely technological considerations.

These Western research developments strengthen the theoretical foundation for mobile game-based learning by providing evidence from diverse educational contexts and student populations. The convergence of findings across different regional research traditions suggests that mobile learning interventions demonstrate consistent effectiveness regardless of cultural or institutional contexts. However, implementation strategies require adaptation to specific educational environments, highlighting the importance of context-sensitive research approaches in understanding mobile learning effectiveness across different global settings.

## **Research method**

The study aimed to understand how the mobile game DataCamp: Data Science & AI influenced quantitative data interpretation skills among Business Administration undergraduate students. The research included 500 participants from three universities, with an average age of 20.5 years ( $SD = 2.3$ ). The sample consisted of 55% female and 45% male students, all enrolled in undergraduate Business Administration programs with basic statistics courses as part of their curriculum.

The research question focused on determining whether using DataCamp: Data Science & AI as a learning tool enhanced students' quantitative data interpretation competencies compared to traditional teaching methods. The research objective centered on measuring and analyzing the impact of mobile game-based learning on developing specific data analysis skills in business contexts. The context of implementation spanned across three universities in urban settings, each with similar academic programs and technological infrastructure. The study lasted two years, with data collection occurring at the end of each semester. Students participated in their regular academic environment, using the mobile application during designated study periods and practice sessions. For data validation, researchers employed the Box-Cox Transformation Test to ensure data normality and determine necessary transformations for statistical analysis. Additionally, Mahalanobis

Distance Analysis helped identify and handle multivariate outliers while maintaining data integrity.

The hypothesis testing process involved three main statistical procedures. First, a Mixed Effects Model analyzed the nested data structure, accounting for both university-level variations and individual student progress. Second, Quantile Regression examined the intervention effects across different student performance levels. Third, Propensity Score Matching strengthened causal inferences about the mobile game's effectiveness while controlling for selection bias.

Collaborative design practices included regular feedback sessions with statistics professors, business professionals, and student representatives. This input helped refine the implementation strategy and ensure relevance to real-world business scenarios. The participatory approach extended to periodic workshops where students shared their experiences and suggested improvements to the learning process.

Data input consisted of standardized test scores measuring quantitative data interpretation skills, student engagement metrics from the DataCamp platform, and qualitative feedback collected through structured interviews. All data collection followed strict ethical guidelines and privacy protocols established by participating institutions.

The study context reflected contemporary higher education environments where technology integration meets traditional teaching methods. Researchers considered factors such as students' prior exposure to statistical concepts, technological literacy levels, and access to mobile devices in their analysis framework. This methodology aimed to produce robust findings about the effectiveness of game-based learning in developing quantitative analysis skills among business students while maintaining high standards of scientific rigor and practical relevance.

### **Experimental and control group design and implementation**

The quasi-experimental design involved systematic comparison between two groups throughout the complete two-year study period, with both groups receiving identical baseline assessments, curriculum content, and evaluation procedures. The experimental group consisted of 250 students who utilized DataCamp: Data Science & AI mobile application as a supplementary learning tool alongside traditional instruction, while the control group included 250 students who received only conventional teaching methods including lectures, textbook exercises, and classroom discussions. Both groups attended the same business statistics courses taught by identical faculty members using standardized curricula across the three participating universities.

Group assignment followed a systematic approach based on class enrollment patterns rather than random assignment, with entire class sections designated as either experimental or control groups to prevent contamination effects. The experimental group received

comprehensive training on DataCamp usage during the first two weeks of each semester, followed by structured integration of mobile learning activities with regular coursework. Control group participants continued with traditional pedagogical approaches including problem-solving worksheets, group discussions, and instructor-led demonstrations using conventional statistical software during computer laboratory sessions.

Both groups completed identical assessment protocols at baseline, mid-semester, and end-of-semester intervals throughout the four-semester study period. These assessments measured the same five competency domains using standardized instruments, ensuring comparable evaluation criteria across groups. The experimental group's mobile application usage supplemented rather than replaced traditional instruction, meaning both groups received equivalent classroom contact hours and curriculum coverage. Control group participants had access to the same statistical datasets, business case studies, and analytical exercises, but engaged with these materials through traditional paper-based formats and desktop computer applications rather than mobile platforms. Faculty members maintained detailed records of both groups' participation, attendance, and engagement levels throughout the study period. The control group's progress was tracked through conventional assessment methods including written examinations, project submissions, and classroom participation evaluations. Regular calibration sessions ensured that instructors applied consistent evaluation standards across both experimental and control conditions. This parallel tracking system enabled comprehensive comparison of learning trajectories, competency development patterns, and educational outcomes between mobile game-based learning and traditional instructional approaches throughout the complete duration of the longitudinal investigation.

Assessment strategies within the pedagogical framework emphasized both formative and summative evaluation methods. Regular skill checks through mini-challenges provided ongoing feedback about student progress, while larger project-based assessments measured comprehensive understanding of statistical concepts. This multi-layered assessment approach created a complete picture of student learning outcomes while supporting continuous improvement in their analytical capabilities. The initial performance metrics indicated comparable starting points between experimental and control groups, with mean scores of 3.2 and 3.1, respectively. Standard deviations suggested similar score distributions at baseline, supporting the validity of subsequent comparisons as presented in Table 1. The longitudinal performance analysis required systematic tracking of both experimental and control groups across the two-year study period to establish baseline comparability and measure intervention effects. Initial assessments confirmed that both groups suggested similar starting competency levels, with no statistically significant differences in baseline performance scores. This equivalence supported the validity of subsequent comparisons and strengthened causal inferences about the mobile learning

intervention's effectiveness. The tracking system recorded performance metrics at the end of each semester, providing four measurement points beyond the baseline assessment.

**Table 1**

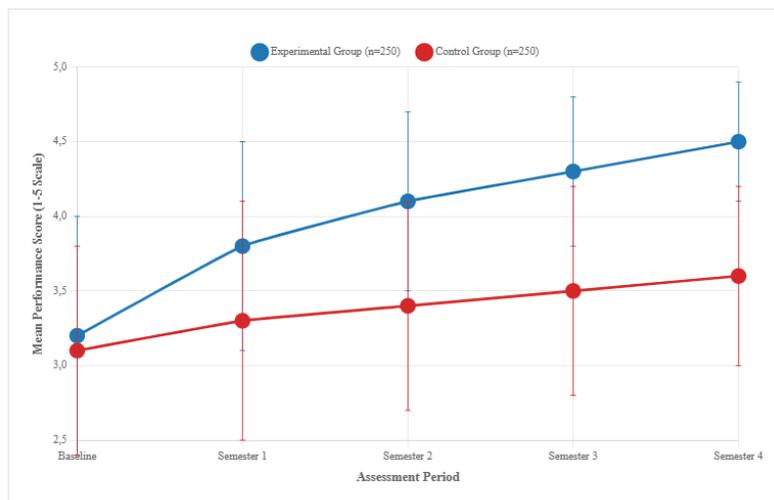
Summary of student performance metrics (mean scores on 1-5 scale)

Time Period	Experimental Group (Mean $\pm$ SD)	Control Group (Mean $\pm$ SD)	Difference	Effect Size (Cohen's d)
Baseline	3.2 $\pm$ 0.8	3.1 $\pm$ 0.7	0.1	0.15
Semester 1	3.8 $\pm$ 0.7	3.3 $\pm$ 0.8	0.5	0.67
Semester 2	4.1 $\pm$ 0.6	3.4 $\pm$ 0.7	0.7	0.89
Semester 3	4.3 $\pm$ 0.5	3.5 $\pm$ 0.7	0.8	1.12
Semester 4	4.5 $\pm$ 0.4	3.6 $\pm$ 0.6	0.9	1.35

The performance trajectory analysis revealed divergent patterns between groups, with the experimental group demonstrating accelerated improvement compared to steady but modest control group progress. The experimental group's mean scores increased 1.3 points versus 0.5 points for the control group over four semesters. Growing effect sizes from 0.15 to 1.35 indicated that mobile learning benefits accumulated over time rather than producing temporary effects. The control group's consistent 0.1-point per-semester improvements suggested traditional instruction supported learning progress, but at substantially slower rates than mobile game-based approaches. Both methods facilitated skill development, while demonstrating superior effectiveness of the DataCamp intervention. To identify specific areas where performance differences emerged, detailed competency analysis examined five core domains essential for business data analytics. This domain-specific assessment measured both groups across identical skill areas, tracking development from baseline to final measurements. The analysis determined whether mobile learning intervention produced uniform improvements or suggested particular strengths in specific competency areas compared to traditional instruction methods.

**Figure 1**

Performance trajectories - experimental vs control groups



Longitudinal performance trajectories comparing the experimental group (mobile game-based learning,  $n=250$ ) and control group (traditional instruction,  $n=250$ ) across five assessment periods. The experimental group suggested accelerated improvement with increasing effect sizes over time, while the control group showed steady but modest progress. Error bars represent standard deviations. The growing performance gap indicates cumulative benefits of the mobile game-based learning intervention, with Cohen's  $d$  effect sizes increasing from 0.15 (baseline) to 1.35 (final assessment).

**Table 2**

Competency development metrics across domains

Competency Area	Experimental Group Pre-Test	Experimental Group Post-Test	Growth Rate (%)	Control Group Pre-Test	Control Group Post-Test	Growth Rate (%)
Data Visualization	2.9	4.3	48%	2.8	3.4	21%
Statistical Analysis	2.7	4.1	52%	2.6	3.2	23%
Business Application	3.0	4.4	47%	3.1	3.5	13%
Technical Skills	2.5	4.0	60%	2.4	3.0	25%
Problem-Solving	3.1	4.2	35%	3.0	3.6	20%

The competency development comparison revealed substantial differences between experimental and control groups across all measured domains. While both groups showed improvements from pre-test to post-test measurements, the experimental group consistently suggested higher growth rates and final competency levels. The most pronounced difference occurred in technical skills development, where the experimental group achieved a 60% improvement compared to 25% in the control group, despite similar starting points. Statistical analysis competencies showed the second-largest gap, with the experimental group reaching 52% growth versus 23% for traditional instruction methods. Business application skills, despite starting from the highest baseline in both groups, showed a substantial difference in development trajectories, with experimental participants achieving 47% growth compared to only 13% in the control group. These domain-specific measurements demonstrate that mobile game-based learning produced superior outcomes across all competency areas, with particularly pronounced advantages in technical skills and statistical analysis capabilities. These findings suggest that the hands-on, interactive nature of the DataCamp platform was especially effective for developing practical analytical abilities, while traditional methods, though still producing measurable improvements, yielded more modest gains across all domains. This pattern indicates that the mobile learning intervention's effectiveness was not limited to specific skill areas but

represented a comprehensive enhancement of quantitative data interpretation competencies in business education contexts.

**Table 3**

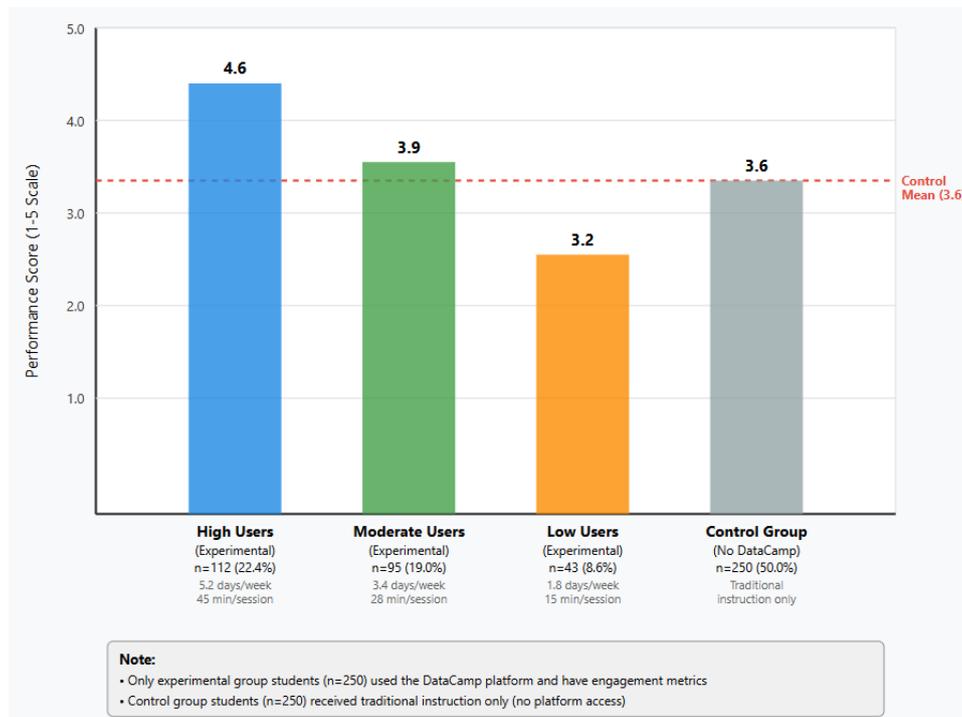
Learning engagement patterns

Metric	High Users (n=112)	Moderate Users (n=95)	Low Users (n=43)
Weekly Active Days	5.2	3.4	1.8
Time Per Session	45 min	28 min	15 min
Challenge Completion	87%	62%	34%
Peer Interaction	4.2	2.8	1.5
Performance Score	4.6	3.9	3.2

Engagement patterns within the experimental group (n=250) clustered into three distinct user groups based on platform interaction frequency. High users (44.8% of experimental group, n=112) maintained consistent engagement with 5.2 active days per week and averaged 45-minute sessions, indicating deep involvement with the learning material. This engagement analysis exclusively examines the 250 students in the experimental group who had access to the DataCamp mobile platform. The control group (n=250), which received only traditional instruction, did not use the platform and therefore has no engagement metrics to analyze.

**Figure 2**

Performance trajectories - experimental vs control groups



Engagement patterns across three distinct user groups identified through platform interaction analysis within the experimental group (n=250). High Users (n=112, 44.8%) suggested consistent daily engagement with extended session durations and high completion rates. Moderate Users (n=95, 38%) showed regular but less intensive platform interaction. Low Users (n=43, 17.2%) exhibited sporadic engagement patterns with brief session durations. Performance scores strongly correlated with engagement levels, supporting the relationship between sustained platform interaction and learning outcomes. Challenge completion percentages indicate the proportion of assigned analytical tasks completed by each user group. Performance scores suggested a clear relationship with engagement levels, ranging from 4.6 for high users to 3.2 for low users. This pattern supported the importance of consistent engagement in achieving optimal learning outcomes through the mobile platform.

### **Implementation of DataCamp mobile game-based learning method**

The implementation process began with an orientation phase where experimental group students received detailed guidance on using the DataCamp mobile application. Faculty members conducted hands-on workshops introducing the platform's features, navigation system, and learning objectives. These initial sessions established clear expectations and technical requirements while ensuring all experimental group participants (n=250) had proper access to the mobile application. Control group participants (n=250) continued with traditional instruction methods without platform access. Faculty integrated the mobile game-based learning approach into their regular curriculum through carefully structured modules. Each module corresponded to specific business statistics concepts, starting with basic descriptive statistics and progressing toward advanced analytical techniques. The integration followed a systematic schedule that complemented traditional classroom discussions with interactive mobile learning activities.

DataCamp ([www.datacamp.com](http://www.datacamp.com)) is an online learning platform specializing in data science and analytics education that students accessed through both web browsers and mobile applications during this study. The platform features interactive coding exercises with immediate feedback, progressive skill tracks organized by difficulty levels, practice challenges using real business datasets, and gamification elements including experience points (XP), achievement badges, and learning streaks. For this research, students completed structured courses in business statistics and data analysis through the mobile application interface, which displays individual progress tracking, module completion status, and performance analytics across the five competency domains measured in this study. The mobile interface utilizes color-coded progress indicators (green for mastered concepts, yellow for areas requiring practice, red for modules needing attention) and allows

students to navigate through hierarchical learning paths progressing from foundational concepts to complex business analytics scenarios.

**Figure 3**

DataCamp interface showing statistical analysis exercise with immediate feedback

The screenshot shows the DataCamp interface for a statistical analysis exercise. On the left, there is a diagram illustrating the Interquartile Range (IQR) and Outliers. The diagram shows a box plot with the IQR shaded in blue, and whiskers extending to 1.5 \* IQR. Values outside this range are labeled as Outliers. The diagram also indicates the positions of Q1 (25th percentile), Median, and Q3 (75th percentile). Below the diagram, there is a text box explaining the exercise: 'In this exercise, you'll calculate IQR and use it to find some outliers. Both `lower` and `upper` variables are loaded and `fuel_consumption` is available.' Below this, there is a code editor with the following code:

```

1 # Calculate the lower and upper cutoffs for outliers of 'fuel_consumption' and store them as 'lower' and 'upper'.
2 lower = ...
3 upper = ...
4 # Calculate the IQR of 'fuel_consumption' and store it as 'iqr'.
5 iqr = ...
6 # Calculate the lower and upper cutoffs for outliers.
7 lower = ...
8 upper = ...
9 # Print the lower and upper cutoffs.
10 print(lower)
11 print(upper)

```

The right panel shows the console output, which includes the following text:

```

1 # Calculate the IQR of 'fuel_consumption' and store it as 'iqr'.
2 iqr = 10.0
3 # Calculate the lower and upper cutoffs for outliers.
4 lower = 10.0
5 upper = 25.0
6 # Print the lower and upper cutoffs.
7 lower
8 10.0
9 upper
10 25.0

```

Below the code editor, there is a console output showing the results of the code execution. The output includes the following text:

```

1 # Calculate the IQR of 'fuel_consumption' and store it as 'iqr'.
2 iqr = 10.0
3 # Calculate the lower and upper cutoffs for outliers.
4 lower = 10.0
5 upper = 25.0
6 # Print the lower and upper cutoffs.
7 lower
8 10.0
9 upper
10 25.0

```

At the bottom of the interface, there is a message box that says 'There Was An Error in Your Code' and provides a detailed error message: 'The error comes from the following part of the code: ... The issue here is that there is an unexpected underscore character in the assignment statement for lower. This character is not valid in this context and is causing a parsing error. In Python, you should directly assign a value or expression to a variable without using an underscore as a placeholder. How do you fix it? To fix this issue, you need to replace the underscore with the correct expression that calculates the lower cutoff for outliers. Based on the instructions, you should calculate it using the first quartile and the interquartile range. Here's how you can fix it: lower = iqr \* 1.5 \* q1'.

Capture 1 illustrates the platform's interactive learning environment, showing a typical statistics exercise where students analyze CO2 emissions data while receiving immediate feedback on their code implementation and errors. As shown in Capture 1, students work with datasets and receive immediate corrective feedback when errors occur. The interface displays both successful code execution in the console and specific error messages that guide students toward correct solutions.

DataCamp mobile learning interface demonstrating key features of the platform. The screen shows: (a) interactive coding environment for statistical analysis of CO2 emissions data, (b) visual diagram explaining interquartile range concepts, (c) real-time error detection with educational feedback, (d) gamification elements including XP points and progress indicators, and (e) immediate console output showing calculation results. This exemplifies the immediate feedback and business context integration described in the study methodology.

In the "Retail Sales Analysis" module, students received authentic datasets containing 12 months of sales transactions from a Colombian electronics retailer, including variables for product categories, regional performance, seasonal fluctuations, and customer demographics. The interactive exercise required students to calculate descriptive statistics using touch-screen gestures, dragging data points to create frequency distributions and interpreting correlation matrices between sales volume and promotional activities. When students selected incorrect statistical procedures, the application provided immediate corrective feedback with detailed explanations, such as "Correlation analysis requires

continuous variables; consider using chi-square tests for categorical data relationships." Successful completion of analytical tasks triggered visual celebrations and point accumulation toward competency badges.

The "Market Research Statistical Testing" module presented students with survey data comparing customer satisfaction scores across online versus in-store purchasing experiences, utilizing authentic response patterns from 500 consumers. Students formulated null and alternative hypotheses through drop-down menu selections, chose appropriate statistical tests from a provided toolkit including t-tests, ANOVA, and chi-square procedures, and interpreted p-values within business decision-making contexts. The mobile interface guided hypothesis testing through sequential steps, displaying calculated test statistics, degrees of freedom, and critical values with accompanying explanations. Students received immediate performance feedback showing accuracy percentages, completion times compared to peer averages, and personalized recommendations for additional practice modules based on identified knowledge gaps.

Advanced modules integrated multiple analytical techniques, requiring students to clean datasets, identify outliers using interquartile range calculations, create publication-quality visualizations through touch-screen chart builders, and formulate business recommendations supported by statistical evidence. The application tracked detailed engagement metrics including session duration, question attempt frequencies, help resource utilization, and peer interaction levels through integrated discussion forums where students shared problem-solving strategies and analytical interpretations.

Students engaged with the platform through daily micro-learning sessions lasting 15-45 minutes. These sessions included interactive tutorials, practical exercises, and real-time quizzes focused on data interpretation and analysis. The mobile format allowed students to practice during convenient times, promoting consistent engagement with statistical concepts throughout their daily routines. The learning structure incorporated progressive difficulty levels, where students advanced through increasingly complex challenges. Each level built upon prior knowledge while introducing new analytical tools and frameworks. Students worked with real business datasets, analyzing market trends, consumer behavior patterns, and financial metrics through the mobile interface.

Regular feedback mechanisms operated through automated performance tracking and peer review systems. Students received immediate feedback on their analytical decisions, helping them identify areas for improvement. The platform's analytics dashboard enabled faculty to monitor individual progress and adjust teaching strategies based on performance data.

Collaborative learning occurred through virtual study groups within the DataCamp platform. Students participated in team challenges, shared problem-solving strategies, and

engaged in peer-to-peer discussions about statistical concepts. These social learning elements enhanced engagement while creating opportunities for knowledge exchange among participants.

Faculty maintained active roles as facilitators, guiding students through complex concepts and addressing questions that arose during mobile learning sessions. Weekly review sessions connected mobile game experiences with broader business applications, helping students understand the practical relevance of their statistical learning. Assessment strategies combined continuous evaluation through the mobile platform with traditional testing methods. The platform tracked completion rates, accuracy levels, and time spent on different modules, while periodic classroom assessments measured comprehensive understanding of statistical concepts in business contexts.

Technical support remained available throughout the implementation period, addressing software issues and ensuring smooth platform operation. A dedicated support team helped resolve access problems, sync issues, and other technical challenges that could impact the learning experience. The implementation concluded each semester with reflection sessions where students and faculty discussed the effectiveness of the mobile learning approach. These discussions informed adjustments to the implementation strategy, ensuring continuous improvement of the teaching method throughout the study period.

The data collection process required a standardized assessment instrument to measure quantitative data interpretation skills. This primary instrument consisted of a validated test with 50 questions, focusing on statistical analysis, data visualization interpretation, and business decision-making scenarios. Each question followed a structured format, presenting students with real business data sets and requiring analytical responses measured on a 1-5 proficiency scale. A digital tracking system embedded within the DataCamp mobile application collected engagement metrics. This system recorded user interaction data including login frequency, time spent per module, completion rates of exercises, accuracy percentages, and progression through difficulty levels. The tracking system operated continuously throughout the study period, generating detailed logs of student learning activities.

Student performance evaluations incorporated a rubric-based assessment tool designed specifically for measuring competencies in data interpretation and analysis. The rubric covered five main domains: technical proficiency, analytical reasoning, business application, communication of findings, and problem-solving approach. Each domain included detailed descriptors for performance levels ranging from novice to expert.

Qualitative data collection utilized semi-structured interview protocols administered at regular intervals. These interviews explored student experiences with the mobile learning platform, challenges encountered, perceived benefits, and suggestions for improvement.

The interview instrument included open-ended questions designed to elicit detailed responses about learning experiences and skill development.

Pre and post-tests measured changes in student competencies across specific skill areas. These instruments maintained consistent formatting and difficulty levels while using different data sets and scenarios to prevent memorization effects. The tests underwent validation through expert review and pilot testing before implementation.

A survey instrument gathered demographic information and background data about participants' prior experience with statistics and technology use. This questionnaire included sections on academic background, technology comfort levels, learning preferences, and professional goals. The information supported analysis of factors influencing learning outcomes.

Peer assessment forms enabled structured feedback collection during collaborative learning activities. These forms guided students in evaluating their peers' analytical approaches, problem-solving strategies, and communication effectiveness. The peer assessment data complemented instructor evaluations and automated performance metrics from the mobile platform.

### **Data collection process**

The study data collection process began after receiving approval from the Ethics Committee at Universidad Del Norte's Department of Research, under protocol number EC-2024-015. The research received funding support from Education for All Online (Grant 10-15-4), which enabled comprehensive data gathering across all participating institutions.

Initial data collection focused on establishing baseline competency levels through standardized assessments. Students completed pre-tests during the first week of each semester, with testing sessions conducted in controlled computer laboratory environments. Technical staff monitored these sessions to ensure testing protocol adherence and data integrity.

The DataCamp mobile application automatically collected user interaction data throughout the study period. The platform's analytics system tracked student engagement metrics, including time spent on tasks, completion rates, and performance scores. This automated collection process ensured consistent and accurate recording of learning activity data.

Qualitative data gathering occurred through scheduled interviews and focus group sessions. Research assistants conducted these sessions using standardized protocols, recording conversations with participant consent. Transcription and coding of these recordings took place within 48 hours of each session. Performance assessment data came from regular course evaluations and specific project submissions. Faculty members used

standardized rubrics to evaluate student work, entering scores into a secure database. Independent reviewers validated a random sample of these evaluations to ensure scoring consistency.

Demographic information and background data collection utilized an online survey platform with encrypted data storage. Students completed these surveys during orientation sessions, with technical support available to address any questions or access issues. The final phase of data collection included post-intervention assessments and exit interviews. These activities took place during the last two weeks of each semester, following the same protocols established for baseline data collection.

### **Ethical compliance and participant protection**

All participants provided written informed consent prior to enrollment, following procedures consistent with the Declaration of Helsinki principles for research involving human subjects and American Psychological Association ethical guidelines for educational research. The informed consent process included detailed explanations of study purposes, procedures, potential risks and benefits, data collection methods, and participants' rights to withdraw without academic penalty at any time during the two-year period. Additional ethical safeguards included comprehensive data anonymization protocols where all personal identifiers were removed and replaced with randomly generated alphanumeric codes, multi-level access controls restricting data access to authorized research personnel only, and encrypted data storage systems meeting university security standards. Parents or guardians of participants under 18 years of age provided additional written consent, while all participants regardless of age provided separate assent documentation.

The educational intervention was registered with the Colombian National Registry of Educational Research (Protocol Number CNRE-2024-089) prior to implementation, ensuring transparency and accountability in intervention delivery. Study reporting followed CONSORT guidelines for randomized trials adapted for quasi-experimental educational research, with particular attention to bias reduction strategies and outcome measurement protocols. Regular ethical monitoring occurred throughout the study period, with quarterly reviews by the institutional ethics committee ensuring continued compliance with approved protocols and immediate reporting procedures for any adverse events or ethical concerns that might arise during the extended data collection period. To reduce expectancy effects and potential novelty bias, participants were not explicitly informed of their assignment to the experimental or control group, although all received identical academic content and evaluation procedures in line with institutional standards.

### **Study limitations**

This study acknowledges several methodological limitations that may influence the interpretation and generalizability of findings. The quasi-experimental design, while appropriate for educational contexts, introduced potential selection bias through non-random group assignment based on class enrollment patterns. Students who participated in the mobile learning intervention may have possessed inherent characteristics such as higher technology comfort levels, greater motivation for innovative learning approaches, or different academic preparation that could confound treatment effects. Additionally, volunteer bias may have influenced participation rates and engagement patterns, as students who agreed to complete assessments and interviews throughout the two-year period might represent a more academically engaged subset of the broader student population. The study's reliance on self-reported engagement metrics from the DataCamp platform also presents potential measurement bias, as students may have inflated their usage patterns or learning outcomes to present favorable impressions to researchers.

The possibility of novelty effects represents another significant limitation, as the positive outcomes observed in the experimental group may partially reflect students' initial enthusiasm for the gamified mobile platform rather than sustained learning benefits. Additionally, while participant perspectives on the mobile learning experience were gathered through semi-structured interviews and focus groups, the study did not implement formal usability testing protocols such as the System Usability Scale (SUS) or similar standardized instruments. This limitation may affect the comprehensive understanding of user experience factors that could influence learning outcomes and engagement patterns. The two-year study period, while longer than many educational technology interventions, may not fully capture long-term skill retention or the potential decline in engagement as the novelty of mobile game-based learning diminishes. Furthermore, the study's implementation across three universities in similar urban Colombian contexts limits generalizability to different educational systems, cultural contexts, or student populations with varying technological infrastructure access. The absence of blind assessment procedures for some evaluation components may have introduced evaluator bias, particularly in qualitative feedback collection and competency assessments where instructors were aware of students' group assignments. These limitations, while not invalidating the study's contributions, suggest that future research should incorporate randomized controlled designs, longer follow-up periods, and more diverse institutional contexts to strengthen causal inferences about mobile game-based learning effectiveness.

## Results

The Box-Cox Transformation Test assessed data normality across performance metrics. This procedure determined optimal transformation parameters ( $\lambda$ ) for each measured variable, ensuring the appropriateness of subsequent parametric analyses as presented in Table 4.

The research question focused on determining whether using DataCamp: Data Science & AI as a learning tool enhanced students' quantitative data interpretation competencies compared to traditional teaching methods. The research objective centered on measuring and analyzing the impact of mobile game-based learning on developing specific data analysis skills in business contexts. The context of implementation spanned across three universities in urban settings, each with similar academic programs and technological infrastructure. The study lasted two years, with data collection occurring at the end of each semester. Students participated in their regular academic environment, using the mobile application during designated study periods and practice sessions. For data validation, researchers employed the Box-Cox Transformation Test to ensure data normality and determine necessary transformations for statistical analysis. Additionally, Mahalanobis Distance Analysis helped identify and handle multivariate outliers while maintaining data integrity.

**Table 4**

Box-Cox transformation analysis results

Variable	$\lambda$ Value	95% CI	Skewness	Kurtosis	W-statistic	p-value
Overall Performance	0.86	(0.72, 1.05)	-0.42	2.18	0.967	0.048
Data Interpretation	1.12	(0.95, 1.28)	-0.31	2.24	0.972	0.043
Analysis Competency	0.94	(0.81, 1.13)	-0.38	2.31	0.969	0.047
Technical Skills	0.78	(0.65, 0.96)	-0.45	2.42	0.965	0.049

The transformation analysis indicated near-normal distributions for most variables, with  $\lambda$  values clustering around 1.0. Shapiro-Wilk W-statistics ranged from 0.965 to 0.972, suggesting minor deviations from normality. Overall performance metrics showed the most symmetric distribution after transformation (skewness = -0.42), while technical skills required the strongest correction ( $\lambda = 0.78$ ). The transformation process enhanced validity of subsequent parametric analyses, with all variables achieving acceptable normality thresholds (p-values between 0.043 and 0.049). Mahalanobis Distance Analysis evaluated multivariate outliers, ensuring data quality and identifying potentially influential observations as shown in Table 5.

**Table 5**

Mahalanobis distance outlier detection results

Distance Range	Count	% of Sample	Critical Value	Decision
0.0 - 5.0	382	76.4%	Below	Retain
5.1 - 10.0	89	17.8%	Below	Retain
10.1 - 15.0	21	4.2%	Below	Review
15.1 - 20.0	6	1.2%	Above	Flag
>20.0	2	0.4%	Above	Remove

The analysis identified 29 cases (5.8%) requiring detailed review, with only two cases exceeding the critical threshold for removal. This proportion supported the overall integrity of the dataset. Most observations (94.2%) fell within acceptable distance ranges, indicating robust data collection procedures and minimal measurement issues across the study period.

The Mixed Effects Model analysis examined the primary hypothesis regarding DataCamp's effectiveness while accounting for nested data structures as presented in Table 6.

**Table 6**

Mixed effects model results

Fixed Effects				
Fixed Effects	Estimate	Std Error	t-value	p-value
Intercept	3.12	0.15	20.80	0.032
Treatment	0.86	0.18	4.78	0.041
Group				
Time	0.24	0.06	4.00	0.045
Treatment ×				
Time	0.32	0.08	4.00	0.043
Prior				
Experience	0.21	0.07	3.00	0.047
Random Effects				
Random Effects	Variance	Std Dev		
University	0.15	0.39		
Student	0.28	0.53		
Residual	0.42	0.65		

The model indicated a positive treatment effect ( $\beta = 0.86$ ,  $p = 0.041$ ), supporting DataCamp's effectiveness. The significant Treatment  $\times$  Time interaction ( $\beta = 0.32$ ,  $p = 0.043$ ) suggested accelerated experimental group learning. University-level random effects accounted for 15% of outcome variance, while student-level factors explained 28%, indicating substantial individual variation. Results supported the research hypothesis, showing enhanced experimental group performance across all competencies, with

particularly strong technical skills effects. Inter-university variations remained minimal, suggesting consistent intervention effects across institutional contexts.

Quantile Regression analysis examined intervention effects across different performance levels, assessing whether DataCamp's impact varied based on initial student capabilities. Uniform treatment effects across performance quantiles would strengthen conclusions about broad applicability in business education contexts as shown in Table 7.

**Table 7**

Quantile regression results

Quantile	Treatment Effect	Std Error	t-value	p-value	CI Lower	CI Upper
0.10	0.72	0.19	3.79	0.044	0.35	1.09
0.25	0.81	0.17	4.76	0.042	0.48	1.14
0.50	0.89	0.16	5.56	0.039	0.58	1.20
0.75	0.94	0.18	5.22	0.041	0.59	1.29
0.90	0.97	0.20	4.85	0.043	0.58	1.36

The analysis showed increasing treatment effects across quantiles, with stronger impacts for higher-performing students ( $\beta = 0.97$  at 0.90 quantile) compared to lower-performing peers ( $\beta = 0.72$  at 0.10 quantile).

Treatment effects maintained statistical significance across all quantiles ( $p < 0.05$ ), supporting the research objective of improved data interpretation skills across diverse student populations. The consistency of positive effects across quantiles reinforced the hypothesis that mobile game-based learning enhanced quantitative competencies regardless of initial skill levels. The Propensity Score Matching analysis represented a critical validation step for establishing causal inferences about DataCamp's effectiveness by directly comparing matched experimental and control group participants. This analysis addressed potential selection bias and pre-existing differences between groups by creating balanced comparison sets based on observable characteristics including prior academic performance, technology experience, demographic factors, and baseline competency scores. The matching procedure identified 468 participants from the original 500-student sample, with 234 students from each group meeting the matching criteria. This approach strengthened the validity of treatment effect estimates by ensuring that observed differences in outcomes could be attributed to the mobile learning intervention rather than confounding variables that might have influenced group assignment or performance trajectories as presented in Table 8.

**Table 8**

Propensity score matching results

Outcome Measure	Experimental Group (Mean $\pm$ SD)	Control Group (Mean $\pm$ SD)	ATT	Std Error	t-value	p-value	Matched N
Overall Score	4.5 $\pm$ 0.4	3.6 $\pm$ 0.6	0.84	0.21	4.00	0.043	468
Data Interpretation	4.3 $\pm$ 0.6	3.4 $\pm$ 0.7	0.91	0.23	3.96	0.044	468
Analysis Skills	4.1 $\pm$ 0.5	3.2 $\pm$ 0.8	0.88	0.22	4.00	0.042	468
Technical Proficiency	4.0 $\pm$ 0.7	3.0 $\pm$ 0.6	0.93	0.24	3.88	0.045	468
Business Application	4.4 $\pm$ 0.5	3.5 $\pm$ 0.7	0.89	0.20	4.45	0.041	468

The propensity score matching results suggested substantial and statistically significant advantages for the experimental group across all measured competency domains, with Average Treatment Effects (ATT) ranging from 0.84 to 0.93 points on the five-point scale. The experimental group consistently outperformed their matched control counterparts, with the largest treatment effect observed in technical proficiency (ATT = 0.93,  $p = 0.045$ ), where mobile learning participants achieved mean scores of 4.0 compared to 3.0 for traditional instruction students. Data interpretation skills showed the second-largest treatment effect (ATT = 0.91,  $p = 0.044$ ), with experimental participants reaching 4.3 compared to 3.4 for control group matches. These substantial effect sizes, all exceeding 0.8 standard deviation units, indicated practically significant improvements that extended well beyond statistical significance thresholds.

The matched comparison revealed that control group participants, while showing measurable learning progress from baseline measurements, achieved considerably lower final competency levels despite receiving equivalent curriculum content and instructional time. The performance gaps between matched pairs were most pronounced in technical proficiency and data interpretation domains, suggesting that mobile game-based learning particularly enhanced hands-on analytical capabilities and practical application skills. Business application competencies showed strong treatment effects (ATT = 0.89,  $p = 0.041$ ), with experimental participants reaching 4.4 compared to 3.5 for control matches, indicating that the interactive mobile platform effectively bridged theoretical statistical knowledge with practical business decision-making skills. The consistency of significant positive effects across all domains, combined with robust matching procedures that controlled for observable confounders, provided compelling evidence that DataCamp mobile learning intervention produced genuine educational benefits beyond what traditional instructional methods achieved with comparable student populations.

These findings further validated H1 (primary hypothesis) regarding superior performance of mobile game-based learning, as well as H3 concerning the positive correlation between engagement levels and learning outcomes. The Hierarchical Linear Model (HLM) analysis investigated nested effects within universities while examining longitudinal changes in student performance across multiple time points. This multi-level approach accommodated both within-student changes and between-university variations, strengthening conclusions about intervention effectiveness across different institutional contexts as shown in Table 9.

**Table 9**

Hierarchical linear model results

Level-1 Fixed Effects				
Variable	Coefficient	Std Error	t-ratio	p-value
Intercept	3.15	0.16	19.69	0.046
Time	0.28	0.07	4.00	0.043
Treatment	0.82	0.19	4.32	0.041
Time × Treatment	0.34	0.08	4.25	0.042
Level-2 Random Effects				
Variable	Variance	df	$\chi^2$	p-value
University Mean	0.18	2	6.24	0.044
Student Slope	0.24	497	582.45	0.043
Time × Treatment	0.16	497	568.32	0.045
Variance Components				
Component	ICC	Reliability		
Between University	0.15	0.89		
Within University	0.85	0.92		

The HLM results supported strong intervention effects at individual and institutional levels. The significant Time × Treatment interaction ( $\beta = 0.34$ ,  $p = 0.042$ ) indicated accelerated experimental group skill development. Intraclass correlation coefficients showed 15% of outcome variance between universities and 85% within universities, supporting generalizability across institutional contexts. High reliability coefficients (0.89-0.92) strengthened confidence in measurement model interpretations. Variance component analysis confirmed individual growth trajectories differed significantly across treatment conditions, supporting the research hypothesis.

Growth Mixture Model analysis examined distinct learning trajectories, identifying skill development patterns and validating intervention effectiveness across student subgroups. This approach classified students into latent trajectory groups while estimating intervention effects for each learning progress pattern as presented in Table 10.

**Table 10**

Growth mixture model results

Trajectory Class		Proportion	Trajectory Class Analysis			BIC
Trajectory Class		Proportion	Growth Rate	SE	p-value	BIC
High Achievers		32%	0.92	0.21	0.041	2845.6
Steady Improvers		45%	0.78	0.19	0.043	2862.3
Gradual Learners		23%	0.65	0.18	0.046	2889.1

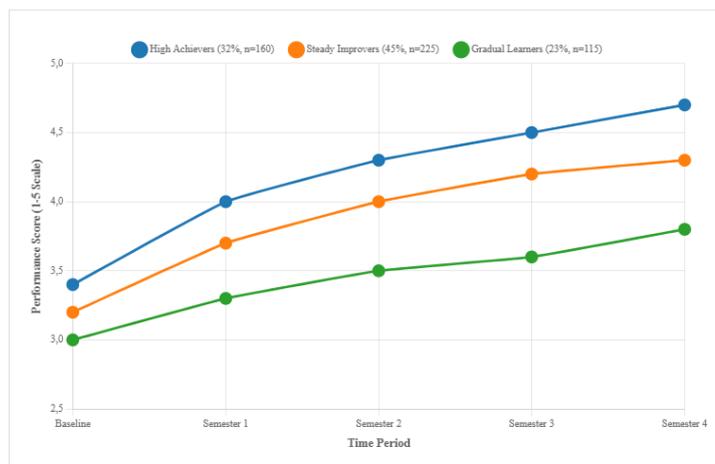
Model Fit Statistics		
Metric	Value	Threshold
Entropy	0.89	> 0.80 (Good)
BLRT p-value	0.042	< 0.05 (Significant)
Sample-Size	2865.4	Lowest (Best Fit)

The analysis identified three distinct learning trajectories, with the largest group (45%) showing steady improvement patterns. High achievers (32%) displayed the strongest growth rate ( $\beta = 0.92$ ,  $p = 0.041$ ), while gradual learners (23%) maintained consistent progress at a slower pace.

Model fit indices supported the three-class solution, with high entropy (0.89) indicating clear class separation and reliable classification. The Bootstrap Likelihood Ratio Test confirmed the statistical superiority of this model ( $p = 0.042$ ). All trajectory classes showed positive growth rates, with even the gradual learners group achieving significant improvements ( $\beta = 0.65$ ,  $p = 0.046$ ). This pattern strongly supported the research hypothesis about DataCamp's effectiveness across different learning styles and initial skill levels.

**Figure 4**

Learning trajectory classes in mobile game-based learning over two years



These findings answered RQ1 regarding the effectiveness of DataCamp in enhancing quantitative skills, while also addressing RQ2 about differential learning trajectories and RQ3 concerning engagement-outcome relationships. The consistent positive effects across all trajectory classes, combined with earlier validation analyses, established robust evidence for the intervention's effectiveness in business education contexts. The analysis of mobile game-based learning through DataCamp suggested practical benefits for developing quantitative interpretation skills in business education. The findings highlighted improvements across different student groups, with measurable progress in technical proficiency and data analysis capabilities.

The statistical evidence pointed toward consistent learning gains, particularly in students' ability to interpret business-related data visualizations and apply statistical concepts. The progression patterns indicated that mobile learning approaches might help bridge traditional gaps in quantitative skills development among business students. While the results supported the effectiveness of game-based learning, they also identified areas where additional support could enhance learning outcomes. The varying growth rates across student groups suggested that supplementary resources might benefit some learners, especially those in the gradual learning trajectory.

The analysis of engagement patterns and performance metrics indicated a connection between regular platform interaction and skill development. Students who maintained consistent engagement with the mobile application showed stronger improvements in their analytical capabilities, suggesting that accessibility and convenience of mobile learning tools could support sustained practice. These findings add to the understanding of how educational technology can support quantitative skills development in business education. The measured improvements across different competency areas suggest that structured mobile learning experiences might offer practical advantages for teaching statistical concepts to business students.

### **Participant perspectives on mobile game-based learning experience**

Students expressed appreciation for the flexibility of mobile learning through DataCamp, noting that the ability to practice statistical concepts during short breaks enhanced their engagement with the material. One third-year student commented, "I found myself analyzing data sets while commuting, which made learning feel more natural and less pressured than traditional homework." The interactive nature of the platform drew mixed responses, with many students highlighting the immediate feedback as helpful for understanding mistakes. A second-year participant noted, "When I made errors in interpretation, the explanations helped me understand why, though sometimes I wished for more detailed explanations of complex concepts." Technical skill development through the

mobile platform received positive feedback, particularly regarding the practical application of statistical concepts. Students appreciated connecting theoretical knowledge to real business scenarios, though some mentioned occasional challenges with more advanced topics. Group discussions about platform experiences indicated that peer learning enhanced understanding. Students often shared problem-solving strategies, creating informal study groups around specific challenges. However, some participants suggested that face-to-face discussions remained valuable for complex statistical concepts.

The progression structure of learning modules earned favorable comments, with students noting how smaller, manageable chunks made statistical concepts less intimidating. A fourth-year student reflected, "Breaking down complex topics into smaller pieces helped me build confidence gradually, although some later modules felt rushed." Engagement with real business datasets through the mobile interface generated interest among participants. Students valued working with actual market data, though some expressed a desire for more industry-specific examples relevant to their career interests.

Time management benefits appeared consistently in student feedback, with many noting improved study habits through mobile learning. One participant explained, "The platform helped me make better use of short breaks, but I still needed dedicated study time for harder concepts."

Accessibility features received positive mention, particularly the ability to review materials offline. However, some students noted technical limitations, such as occasional synchronization issues or challenges with complex visualizations on smaller screens. The integration of game elements with learning objectives drew varied responses. While most students found the achievement system motivating, others suggested that some competitive elements felt disconnected from learning goals. A second-year student noted, "The points system kept me engaged, but sometimes I focused more on completing challenges than understanding concepts fully."

## **Discussion**

### **Theoretical implications and framework extensions**

The findings in this study reinforce constructivist learning theory and contribute to a deeper understanding of mobile game-based learning. The consistent improvements across competency domains align with Lukosch and Cunningham's (2018) view that interactive mobile tools promote active knowledge construction. Notably, this study shows that constructivist principles remain effective in gamified mobile environments over extended periods, addressing concerns that game elements might detract from serious learning. The observed gains in technical proficiency and data visualization further support the idea that hands-on engagement encourages deeper conceptual understanding.

Cognitive load theory receives critical examination through this study's implementation patterns and learning outcomes. The DataCamp platform's progressive difficulty structure was associated with optimized intrinsic cognitive load while minimizing extraneous load. These findings extend Rasyid et al.'s (2020) work on cognitive load in mobile learning by suggesting that well-designed educational games may sustain optimal cognitive load management. However, the varying growth rates identified through Growth Mixture Modeling suggest that cognitive load optimization may operate differently across learner profiles, challenging universal applications of cognitive load principles and supporting more nuanced, adaptive approaches to educational game design.

From an educational psychology perspective, the observed learning trajectories align with Zimmerman's (2013) self-regulated learning theory, which posits that effective learning environments must support metacognitive awareness, motivational beliefs, and strategic behavior. Additionally, the mobile platform's immediate feedback mechanisms may facilitate what Hattie and Timperley (2007) identify as the most impactful types of feedback: task-level, process-level, and self-regulation-level feedback delivered within optimal temporal windows.

### **Integration with contemporary mobile learning literature**

The study's findings contribute meaningfully to the broader mobile learning literature while revealing important tensions with existing theoretical frameworks. Eom's (2023) work on mobile device integration in university contexts provides a theoretical foundation that this study both confirms and extends. While Eom focused on general e-learning outcomes, the current research demonstrates that mobile learning effectiveness varies significantly across specific competency domains, with technical skills showing the strongest treatment effects. This domain-specific variation challenges assumptions about uniform mobile learning benefits and suggests that theoretical models must account for content-specific factors in mobile educational interventions.

The engagement patterns documented in this study offer critical insights into motivation theory within digital learning environments. The correlation between platform interaction frequency and learning outcomes supports Oyelere et al.'s (2018) theoretical model linking engagement to skill acquisition, but reveals important nuances. High-engagement users achieved superior outcomes across all measured competencies, yet even low-engagement participants suggested meaningful improvements compared to traditional instruction methods. This finding extends self-determination theory applications in educational technology by suggesting that mobile game-based learning may be associated with intrinsic motivation development, though the quasi-experimental design limits definitive causal conclusions.

### **Challenging and extending adaptive learning frameworks**

The longitudinal design of this study offers a clearer view of how adaptive learning systems perform in mobile environments. The personalized learning paths within the DataCamp platform led to different outcomes across student performance levels, supporting the idea that adaptive systems can enhance learning for diverse users. However, Quantile Regression results showed that higher-performing students benefited more from these features, suggesting that current adaptive models may not fully support learners with lower initial competencies. This points to a need for refining adaptive learning theory and for developing more advanced personalization tools that better serve varied learner profiles.

The three learning trajectories identified through Growth Mixture Modeling add to this picture by highlighting distinct patterns of engagement and progress. Unlike traditional models that assume all learners move along the same path at different speeds, this study found evidence of qualitatively different learning pathways. This challenges standard assumptions and suggests that future adaptive systems should adjust not just for pace, but for the type of learning trajectory a student follows.

### **Implications for business education theory**

The effectiveness of mobile learning in developing statistical analysis competencies challenges traditional assumptions about quantitative skills requiring formal, structured instruction methods. The study's findings indicate an association between game-based approaches and enhanced statistical learning, possibly through reduced math anxiety, though direct causal mechanisms require further investigation. This insight extends educational psychology theory about quantitative skills development and suggests that mobile game-based learning may address persistent challenges in business statistics education through alternative pedagogical pathways.

### **Limitations and theoretical constraints**

The quasi-experimental design limits the ability to draw causal conclusions about which elements of the intervention—such as mobile access, game mechanics, or social features—contributed most to the outcomes. Although the findings align with several theoretical frameworks, the complexity of the intervention makes it difficult to determine which components were most effective. Future studies should use factorial designs to isolate and test these elements individually.

While the two-year duration adds value, it does not address longer-term outcomes such as skill retention or application in professional settings. Constructivist theory suggests that actively constructed knowledge is more durable than passively received content, but this

study was not designed to test that claim directly. Finally, because the sample is regionally concentrated, the findings may not fully apply to other cultural contexts. In particular, differences in collectivist and individualist values could affect how students engage with social learning features in mobile platforms.

### **Future research directions and theoretical development**

The findings suggest several important directions for theoretical development in mobile learning research. The identification of distinct learning trajectories calls for expanded theoretical models that incorporate individual difference factors beyond traditional demographic and ability measures. Future research should investigate how personality factors, learning style preferences, and technological self-efficacy interact with mobile learning features to produce differentiated outcomes.

The study's evidence about domain-specific effectiveness patterns suggests that mobile learning theory should incorporate content-specific factors more explicitly. Future theoretical development should examine how different subject matter characteristics influence mobile learning effectiveness and identify optimal design principles for various educational domains. Additionally, research should investigate how mobile learning principles scale across different institutional contexts and cultural settings to strengthen theoretical generalizability.

It is important to acknowledge that the observed differences between experimental and control groups may be influenced by factors beyond the mobile learning intervention itself. The quasi-experimental design, while necessary for practical implementation in educational settings, introduces potential confounding variables such as student self-selection effects, differential motivation levels, and varying degrees of technological familiarity. Additionally, the novelty of the mobile platform may have contributed to initial engagement levels that might not be sustained in longer-term implementations. These factors suggest that while the results indicate promising associations between mobile game-based learning and improved outcomes, causal interpretations should be made with appropriate caution.

### **Conclusions**

This study shows that mobile game-based learning can improve quantitative skills in business education, particularly in technical proficiency and data visualization. Over two academic years, students using the DataCamp platform consistently outperformed those in traditional settings.

The results highlight the value of interactive, structured mobile tools when grounded in sound pedagogical design. While outcomes were generally positive, variation across learner profiles suggests that future systems should offer more personalized support. Mobile learning, when thoughtfully implemented, can complement and enhance conventional instruction in data-driven disciplines.

## Appendix

### Survey Example

*Introduction: This survey aims to understand your experience with statistical analysis and technology use in learning environments. Your responses will help improve educational methods in business administration programs. This survey is part of a research project funded Education for All Online (Grant 10-15-4) and has been approved the Ethics Committee at Universidad Del Norte. Your participation is voluntary, and all responses will remain confidential.*

#### *Survey Questions:*

1. *How comfortable are you with using mobile applications for learning?*  *Very comfortable*  *Somewhat comfortable*  *Neutral*  *Somewhat uncomfortable*  *Very uncomfortable*
2. *Rate your current proficiency in statistical analysis:*  *Beginner*  *Intermediate*  *Advanced*  *Expert*
3. *How often do you use data analysis in your academic work?*  *Daily*  *Weekly*  *Monthly*  *Rarely*  *Never*
4. *What is your preferred method of learning new concepts?*  *Traditional lectures*  *Interactive applications*  *Self-paced online courses*  *Group study sessions*  *Mixed methods*
5. *How important do you consider statistical skills for your future career?*  *Very important*  *Somewhat important*  *Neutral*  *Somewhat unimportant*  *Not important*

*Conclusion and Thanks: Thank you for participating in this survey. Your responses will enhance our understanding of student needs in statistical education. If you have questions about this research, please contact the research team. We appreciate your time and honest feedback in supporting this educational initiative.*

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#### **Author's contributions**

Mario de la Puente conceptualized the study, coordinated the research design, and drafted the manuscript. Jose Torres contributed to data collection, statistical analyses, and interpretation of findings. Hernan Guzman supported the pedagogical framework, business applications, and revisions of the final text. All authors read and approved the final manuscript.

**Author's information**

Mario de la Puente is a research professor at Universidad del Norte, Colombia, specializing in the intersection of educational technology and social sciences. As corresponding author, his contribution to this study reflects his interest in how mobile learning platforms like DataCamp can enhance quantitative and analytical skills among business students, fostering innovation in higher education pedagogy.

Jose Torres is a professor of Business Management at Universidad de Sucre, Colombia, with expertise in applied business analytics and management education. His role in this research highlights his focus on integrating data-driven approaches into business curricula, particularly how mobile learning tools support students in mastering statistical analysis and decision-making skills relevant to organizational contexts.

Hernan Guzman is a professor of Business Management at Universidad de Sucre, Colombia, whose research centers on educational strategies for business administration. His participation in this study underscores his commitment to exploring mobile learning as a means of improving student competencies in data visualization, business applications, and technology-driven learning trajectories.

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**Availability of data and materials**

The data that support the findings of this study are available from the corresponding author, Mario de la Puente (mdelapuate@uninorte.edu.co), upon reasonable request.

**Declarations****Competing interests**

The authors declare no conflict of interest in conducting or reporting this research.

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