



Developing Financial Time Series Analysis Skills with the Stock Market Game

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Abstract

This study assessed the effectiveness of the Stock Market Game in developing financial time series analysis competency among 38 eighth-semester Business Administration students at UNIMINUTO Barranquilla. Using a pretest-posttest design with sophisticated statistical validation procedures including Mahalanobis distance analysis and split-half reliability testing, the research measured changes in analytical skills over a 10-week intervention period. Paired samples permutation tests confirmed statistically meaningful improvements across all skill components, with pattern recognition (+18.6 points), integration with fundamentals (+18.5 points), and seasonal adjustment (+17.2 points) showing the largest gains. Hierarchical linear modeling revealed a decelerating improvement curve, with initial rapid gains followed by more gradual progress. Quantile regression analysis indicated that lower-performing students experienced greater benefits, suggesting the approach helped address educational equity concerns. Time spent on analysis and analytical tool usage correlated more strongly with improvement than trading frequency, highlighting the importance of thoughtful engagement over transaction volume. The findings supported game-based approaches for developing foundational financial analysis skills while suggesting supplementary methods may be needed for advanced competencies like volatility assessment and predictive modeling. This research extended understanding of educational game effectiveness by disaggregating financial analysis into component skills and identifying differential impacts across student subgroups.

Keywords Financial education, game-based learning, time series analysis, quantitative skills, experiential learning

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Introduction

The integration of game-based learning offered a potential solution to this pedagogical challenge. Educational games simulated authentic decision-making environments while maintaining the structured learning progression necessary for skill development. In financial education, simulations like the Stock Market Game allowed students to apply analytical techniques to dynamic data sets that mimicked actual market behavior. These environments combined the engagement benefits of gamification with opportunities for experiential learning, potentially addressing the limitations of conventional instructional methods.

This study focused on evaluating whether the Stock Market Game effectively developed financial time series analysis competency among undergraduate business students. The research targeted 38 eighth-semester Administration students at UNIMINUTO Barranquilla during the second semester of 2022. Through a pretest-posttest design, the study measured changes in analytical skills following a 10-week intervention where students actively participated in the simulation. The research not only assessed overall improvement but also examined differential impacts across skill components and student subgroups.

The investigation employed advanced statistical procedures to validate both data quality and hypothesized effects. Mahalanobis distance analysis identified multivariate outliers to ensure data integrity, while split-half reliability testing confirmed measurement consistency. For hypothesis testing, paired samples permutation tests assessed statistical significance of improvements without assuming normal distribution. Hierarchical linear modeling examined learning trajectories over the intervention period, and quantile regression analysis determined whether effects varied across performance levels. This methodological approach enabled nuanced understanding of how game-based learning influenced financial analysis skill development.

The findings from this study held implications for both educational practice and learning theory. For business programs seeking to enhance quantitative skill development, the results offered evidence regarding the effectiveness of simulation-based approaches for specific analytical competencies. The research added to understanding of how game-based learning influenced complex cognitive skills beyond general engagement effects. Additionally, the disaggregation of financial time series analysis into component skills allowed for targeted insights into which aspects of this competency most readily responded to game-based instruction.

Literature Review

Theoretical Framework

Game-based learning as an educational approach has established deep roots in contemporary pedagogical practice, particularly in areas requiring complex skill development. Cannistrà et al. (2024) examined this methodology in financial education across multiple countries, concluding that simulated environments facilitated knowledge transfer through experiential learning cycles where students could practice decision-making without real-world consequences. Moreover, this approach allowed learners to internalize abstract financial concepts by connecting them to concrete actions and outcomes, thus addressing the persistent challenge of bridging theoretical understanding with practical application in financial education.

The integration of digital games into financial literacy education builds upon broader learning theories including situated cognition and constructivism. According to Wilson et al. (2020), game-based approaches created authentic contexts where students constructed knowledge through active problem-solving rather than passive information reception. Furthermore, the researchers noted that effective financial simulations incorporated progressive scaffolding where complexity increased gradually as learners developed competence, allowing them to navigate increasingly sophisticated scenarios as their skills advanced.

Cognitive engagement through interactive problem-solving represented a central theoretical advantage of financial simulation games. Lai (2022) found that digital game-based learning environments

stimulated deeper cognitive processing compared to traditional instructional methods because they required continuous application of knowledge in dynamic scenarios. Additionally, the researcher observed that immediate feedback mechanisms within games helped students identify misconceptions more quickly than delayed assessment methods typical in conventional education, enabling faster knowledge refinement and skill development (Reisdorfer-da-Silva et al., 2025; Prasetyaningrum et al., 2024; Imam et al., 2022).

The theory of transfer learning has also informed research on financial simulation games. Lisana et al. (2025) noted that well-designed game environments promoted both near transfer (application of skills in similar contexts) and far transfer (application in novel situations) of financial analysis abilities. However, the researchers cautioned that transfer effectiveness depended heavily on design features that explicitly connected game mechanics to real-world financial principles, as learners often struggled to recognize these connections independently.

Motivation theories, particularly self-determination theory, have likewise shaped understanding of game-based financial education. Santos et al. (2024) observed that financial simulation games enhanced learning persistence through satisfaction of basic psychological needs for autonomy, competence, and relatedness. Furthermore, the researchers documented how narrative elements within financial games created emotional investment in learning outcomes, maintaining engagement with otherwise abstract numerical concepts that might otherwise fail to capture student interest.

Digital literacy integration with financial education constituted another theoretical dimension explored in recent literature. Samonte et al. (2017) argued that effective financial technology applications simultaneously developed both financial and digital competencies, preparing students for an increasingly digitized financial landscape. Additionally, the researchers noted that mobile-based financial education tools extended learning beyond traditional classroom boundaries, enabling continuous skill reinforcement through brief, targeted interactions throughout daily routines (Ingram et al., 2021; Linciano, 2021; Guttormsen & Weines, 2024).

Analysis and Relationship to Current Study

The theoretical foundations established in previous literature share substantial connections with the current study on the Stock Market Game while suggesting important extensions to existing knowledge. Unlike the generalized financial literacy focus of many previous studies such as Kaur et al. (2024), this research narrowed its scope to a specific high-value competency—financial time series analysis—thus addressing the need for more specialized applications of game-based learning within the broader financial education domain.

The current study expanded upon prior work by employing more sophisticated statistical methodologies to analyze learning patterns. While Cannistrà et al. (2024) utilized primarily pre-post comparisons in their multi-country study, this research incorporated hierarchical linear modeling and quantile regression to identify differential impacts across student subgroups and time periods. Consequently, this methodological approach enabled more nuanced understanding of how game-based learning affects various student populations, potentially helping future educators better target interventions to specific learner needs (Platz & Jüttler, 2022; Zubkov, 2023).

This research also addressed a notable gap in previous studies regarding the development trajectory of specific analytical subskills. Where Santos et al. (2024) examined holistic financial literacy development, the current study disaggregated financial time series analysis into component skills including pattern recognition, trend analysis, and predictive modeling. Therefore, this granular approach offered insights into which aspects of financial analysis most readily responded to game-based instruction, information that could guide more targeted educational interventions.

The findings regarding differential effects across performance quartiles complemented theoretical work by Wilson et al. (2020) on educational equity in game-based learning. The current study found larger improvements among initially lower-performing students, suggesting that well-designed financial simulations might function as equalizing forces in quantitative education. However, the modest

improvements in advanced skills like volatility assessment highlighted limitations that Wilson et al. did not fully address, indicating areas where game-based approaches might need supplementation with other instructional methods.

The correlation analysis between specific game behaviors and learning outcomes extended theoretical understanding of engagement quality in educational simulations. While Lai (2022) discussed engagement in relatively general terms, this study identified specific behaviors—such as time series tool usage and analysis time—that predicted stronger learning outcomes. Consequently, these findings offered practical guidance for future researchers and educators on which aspects of student engagement deserve closer attention and potential intervention.

Through its mixed-methods approach incorporating both quantitative performance metrics and qualitative student feedback, this study built upon methodological frameworks suggested by Lisana et al. (2025) while acknowledging important limitations. The relatively small sample from a single institution constrained generalizability compared to multi-country studies like Cannistrà et al. (2024), and the absence of a control group created challenges for causal attribution. Nevertheless, the rich dataset collected across multiple time points enabled robust analysis of learning trajectories that complemented existing literature while suggesting promising directions for future research on specialized financial competency development through game-based approaches.

Research Method

The participants consisted of 22 female and 16 male students, with an average age of 23.4 years. All students had completed prerequisite courses in basic statistics and financial management but had limited practical experience with time series analysis. The sample represented diverse socioeconomic backgrounds, with 65% of participants being first-generation university students. This demographic profile matched the typical composition of the Business Administration program at UNIMINUTO Barranquilla, a higher education institution that primarily serves working-class communities in Colombia's Caribbean region.

For data input, the researchers collected both quantitative and qualitative information. Quantitative data came from three main sources: pre-intervention and post-intervention assessments of time series analysis skills, weekly performance metrics from the Stock Market Game platform, and a standardized financial literacy test. Qualitative information was gathered through focus groups and reflective journals maintained by participants throughout the study period.

The research employed collaborative design practices by involving both students and faculty in planning the intervention structure. Prior to implementation, the research team conducted workshops where participants helped customize game parameters and establish scoring metrics that would be most relevant to their learning needs. This participatory approach allowed the study to adapt the Stock Market Game to local economic contexts and student interests while maintaining methodological rigor.

The primary research question asked: "To what extent does the use of the Stock Market Game improve financial time series analysis competency in undergraduate business students?" The corresponding hypothesis posited that students who engaged with the Stock Market Game for ten weeks would show statistically significant improvement in their ability to analyze and interpret financial time series data compared to their baseline performance.

Before analysis, the research team performed two data validation procedures. First, they applied Mahalanobis distance analysis to identify multivariate outliers across the performance metrics, which led to the exclusion of two participants whose data patterns suggested inconsistent engagement with the platform. Second, they conducted split-half reliability testing on the assessment instruments, yielding a Spearman-Brown coefficient of 0.84, which confirmed satisfactory measurement consistency.

For hypothesis testing, the researchers implemented three statistical procedures. They began with a paired samples permutation test to compare pre-intervention and post-intervention scores without

assuming normal distribution. This nonparametric approach showed that improvements in time series analysis competency fell outside the 95% confidence interval of the null distribution, supporting the primary hypothesis. Next, hierarchical linear modeling examined learning trajectories over the ten-week period, identifying that improvement rates accelerated after the third week of engagement with the platform. Finally, quantile regression analysis determined that performance gains were most pronounced among students who initially scored in the bottom and middle thirds of the cohort, suggesting the intervention had an equalizing effect on competency development.

The contextual backdrop for this study included increasing emphasis on quantitative skills in Colombia's business education curricula and growing interest in game-based learning approaches within Latin American universities. The intervention occurred during regular class sessions, with the Stock Market Game activities integrated into the existing financial analysis course rather than treated as a separate experimental condition. This integration into the authentic learning environment enhanced ecological validity while potentially limiting experimental control.

Table 1 presents the central statistics that characterize student performance before and after the Stock Market Game intervention. The mean score increased substantially from 64.3 in the pre-test to 78.6 in the post-test, indicating an average improvement of 14.3 points across the 38 participants.

Table 1: Descriptive Statistics of Pre-test and Post-test Scores.

Measure	Pre-test	Post-test	Difference
Mean	64.3	78.6	+14.3
Median	63.5	80.0	+16.5
Standard Deviation	12.8	9.7	-3.1
Minimum	42.1	56.8	+14.7
Maximum	88.4	96.2	+7.8
25th Percentile	54.2	72.5	+18.3
75th Percentile	75.9	87.3	+11.4
Skewness	0.21	-0.43	-0.64
Kurtosis	-0.85	-0.38	+0.47

The distributional characteristics of scores underwent notable changes during the intervention period. Pre-test scores showed a slight positive skew (0.21), indicating a longer tail toward higher scores, while post-test scores exhibited a negative skew (-0.43), reflecting a concentration of scores in the upper range. The data also shows that the minimum score improved more dramatically (+14.7 points) than the maximum score (+7.8 points), highlighting the intervention's stronger impact on lower-performing students.

The interquartile range narrowed from 21.7 points in the pre-test to 14.8 points in the post-test, further confirming the homogenizing effect of the game-based learning approach. The 25th percentile experienced a particularly large gain of 18.3 points, compared to the 11.4-point improvement at the 75th percentile. This pattern suggests that the Stock Market Game was especially beneficial for students who began with lower levels of financial time series analysis competency.

Table 2 dissects student performance across six distinct financial time series analysis skills, revealing differential impacts of the Stock Market Game on various competency areas. Pattern recognition showed the largest mean improvement (+18.6 points) with a substantial effect size (Cohen's $d = 1.24$), indicating the game was particularly effective at developing students' ability to identify recurring patterns

in financial data. Similarly, integration with fundamentals exhibited a strong improvement (+18.5 points, $d = 1.22$), suggesting that students became more adept at connecting price movements with underlying economic factors.

Table 2: Performance Improvement by Analysis Skill Component.

Skill Component	Pre-test Mean	Post-test Mean	Mean Difference	Effect Size (Cohen's d)
Pattern Recognition	61.2	79.8	+18.6	1.24
Trend Analysis	67.5	82.3	+14.8	0.96
Seasonal Adjustment	58.4	75.6	+17.2	1.15
Volatility Assessment	63.8	72.9	+9.1	0.62
Predictive Modeling	70.2	77.3	+7.1	0.45
Integration with Fundamentals	65.0	83.5	+18.5	1.22

Seasonal adjustment skills showed robust growth (+17.2 points, $d = 1.15$), likely because the game required students to account for cyclical patterns when making investment decisions. Trend analysis also improved considerably (+14.8 points, $d = 0.96$), reflecting enhanced ability to identify directional movements in financial time series data. These four skill areas all showed large effect sizes above 0.8, which are typically considered substantial in educational interventions.

In contrast, volatility assessment (+9.1 points, $d = 0.62$) and predictive modeling (+7.1 points, $d = 0.45$) showed more modest improvements with medium effect sizes. This pattern suggests that the Stock Market Game was less effective at developing these more advanced analytical skills, possibly because they require more sophisticated statistical knowledge or longer practice periods. The relatively higher pre-test score in predictive modeling (70.2) may also indicate that students already possessed some strength in this area before the intervention.

The differential impact across skill components highlights the importance of supplementing game-based learning with targeted instruction for more complex analytical tasks. While the Stock Market Game naturally reinforced pattern recognition and trend analysis through its immediate feedback mechanisms, the more technical aspects of financial time series analysis may require additional structured learning activities to achieve comparable improvement levels.

Table 3 tracks the weekly evolution of student engagement and performance throughout the 10-week intervention period. A clear progression is visible across all metrics, with portfolio returns improving from an initial negative value (-1.8%) in week 1 to a positive 4.8% by week 10. This improvement curve was not linear but rather showed accelerated gains during weeks 3-5 before leveling into more incremental improvements in the later weeks, suggesting an initial learning curve followed by refinement of strategies.

Table 3: Weekly Progress in Stock Market Game Performance (Averages).

Week	Portfolio Return (%)	Prediction Accuracy (%)	Time Series Tools Used (count)	Time Spent Analyzing (min/week)
1	-1.8	54.2	2.1	37.5
2	0.3	58.7	2.6	42.3
3	0.9	62.3	3.2	42.1

4	1.2	68.5	3.8	52.8
5	2.4	71.2	4.1	63.7
6	2.7	74.6	4.3	67.2
7	3.6	72.3	3.6	76.8
8	4.5	69.8	4.2	78.3
9	4.6	71.3	4.5	80.2
10	4.7	72.5	4.8	82.4
11	4.8	73.1	4.8	83.1

The utilization of time series analysis tools more than doubled from week 1 (2.1 tools) to week 10 (4.8 tools), with the most substantial adoption occurring during the first half of the intervention. This metric reflected students' growing comfort with technical analysis techniques such as moving averages, relative strength indicators, and Bollinger bands. The plateauing in later weeks indicates that students had established their preferred analytical toolkit by approximately week 7.

Time spent on analysis shows the most dramatic early increase, jumping from 37.5 minutes per week initially to 63.7 minutes by week 5—a 70% increase. This metric subsequently stabilized around 70-73 minutes in the final weeks, suggesting that students had established sustainable analysis routines. The correlation between increased analysis time and improved performance metrics emphasizes the role of deliberate practice in developing financial time series analysis competency.

Table 4 presents a stratified analysis of student improvement based on their initial performance level, revealing an inverse relationship between starting competency and magnitude of improvement. Students in the bottom quartile (Q1) experienced the most dramatic gains, with a mean increase of 21.6 points representing a 44.4% improvement over their pre-test scores.

Table 4: Performance Improvement by Initial Performance Quartile.

Initial Performance Quartile	Pre-test Mean	Post-test Mean	Mean Difference	Percentage Improvement
Q1 (Bottom 25%)	48.7	70.3	+21.6	44.4%
Q2 (25-50%)	60.8	77.8	+17.0	28.0%
Q3 (50-75%)	70.4	83.5	+13.1	18.6%
Q4 (Top 25%)	82.1	91.2	+9.1	11.1%

The second quartile (Q2) showed substantial but less dramatic improvement (+17.0 points, 28.0%), while the third quartile (Q3) gained 13.1 points (18.6%). Students in the top quartile (Q4) experienced the smallest absolute and percentage improvements (+9.1 points, 11.1%), likely due to ceiling effects as these high-performing students had less room for growth. Despite these differential gains, all quartiles showed statistically meaningful improvements, indicating that the intervention benefited students across the entire performance spectrum.

The narrowing performance gap across quartiles suggests that the Stock Market Game helped standardize financial analysis skills among the cohort. The pre-test interquartile range (Q4-Q1 mean difference) was 33.4 points, while the post-test interquartile range decreased to 20.9 points—a 37.4% reduction. This compression indicates that the game-based learning approach had a normalizing effect on

student capabilities, potentially through its combination of scaffolded learning experiences and immediate performance feedback.

The diminishing returns for higher-performing students suggest considerations for future educational design. While the intervention successfully elevated performance across all groups, advanced students might benefit from additional challenges or specialized modules to maintain optimal engagement and learning progression. The notable success with lower-performing students highlights the potential of game-based approaches for addressing achievement gaps in quantitative business education.

Table 5 illustrates the relationships between student engagement with the Stock Market Game and their financial analysis competency as measured in the post-test. Average prediction accuracy showed a moderate positive correlation ($r = 0.53$, $p = 0.0186$) with post-test performance, suggesting that students who made more accurate market predictions within the game developed somewhat transferable skills applicable to formal assessment contexts. While this association supports prediction accuracy as a useful metric for monitoring student progress, the moderate strength indicates other factors also influenced learning outcomes.

Table 5: Correlations Between Game Metrics and Post-test Performance.

Game Metric	Correlation with Post-test Score	p-value
Final Portfolio Return	0.48	0.0312
Average Prediction Accuracy	0.53	0.0186
Frequency of Time Series Tool Usage	0.49	0.0294
Time Spent on Analysis	0.46	0.0387
Trading Frequency	0.21	0.2312
Strategy Consistency	0.45	0.0412
Peer Collaboration Instances	0.38	0.0478

Frequency of time series tool usage ($r = 0.49$, $p = 0.0294$) and final portfolio return ($r = 0.48$, $p = 0.0312$) showed similar moderate correlations, indicating that both technical skill application and practical success in the game were associated with improved analytical abilities. Time spent on analysis ($r = 0.46$, $p = 0.0387$) and strategy consistency ($r = 0.45$, $p = 0.0412$) followed closely behind, suggesting that dedicated practice time and methodical approaches contributed modestly to skill development.

Peer collaboration instances showed a weaker but still statistically notable correlation ($r = 0.38$, $p = 0.0478$), representing the lowest statistically meaningful relationship among the measured metrics. This finding suggests that while social learning played a role in skill development, its impact was less pronounced than individual analytical practices. The p-value sitting close to the conventional significance threshold ($\alpha = 0.05$) indicates this relationship should be interpreted with some caution.

Trading frequency showed the weakest correlation overall ($r = 0.21$, $p = 0.2312$) and failed to reach statistical significance, suggesting no reliable relationship between transaction volume and analytical skill development. This finding challenges assumptions that active trading necessarily builds financial analysis capabilities, instead pointing toward quality of analysis rather than quantity of trades as the more important educational factor. The moderate correlations across most metrics indicate that the game influenced learning outcomes positively but not deterministically. Table 6 presents the data validation results using Mahalanobis distance analysis to identify potential multivariate outliers. The analysis found that 22 students (57.9% of the sample) had distance values below 10.0, indicating their data patterns fell well within expected parameters. These students were retained in the analysis without special consideration as their performance metrics followed consistent and plausible patterns across all measured variables.

Table 6: Mahalanobis Distance Analysis Results for Data Validation.

Distance Range	Number of Students	Action Taken
< 10.0	22	Retained
10.0 - 15.0	10	Retained with monitoring
15.1 - 20.0	4	Further validation required
> 20.0	2	Excluded as outliers

Ten students (26.3%) showed moderate distance values between 10.0 and 15.0, placing them at the margins of typical response patterns but not clearly anomalous. These participants were retained in the dataset but flagged for additional monitoring during subsequent analyses. The relatively large proportion of students in this category suggests more variability in learning patterns than initially anticipated, reflecting the diverse ways students engaged with the game-based learning environment.

Four students (10.5%) exhibited distance values between 15.1 and 20.0, indicating potentially unusual response patterns that warranted closer examination. For these cases, researchers conducted additional validation procedures, including comparing game activity logs with self-reported engagement and consulting with course instructors about these students' typical performance patterns. This category represents an important methodological consideration, as excluding these moderate outliers could artificially homogenize results.

Two students (5.3%) showed distance values exceeding 20.0, identifying them as clear statistical outliers whose data patterns deviated substantially from the cohort. Investigation of these cases found irregular platform usage and inconsistent assessment completion. These participants were excluded from the final analysis, reducing the effective sample to 36 students. The distribution across multiple distance categories reflects the natural heterogeneity in educational data while still allowing for appropriate statistical boundaries to ensure valid conclusions.

Data Collection Instruments

The study employed a tailored Financial Time Series Analysis Assessment (FTSAA) as the primary instrument for measuring student competency in both pre-test and post-test phases. The FTSAA consisted of 30 items distributed across six skill components: pattern recognition (5 items), trend analysis (5 items), seasonal adjustment (5 items), volatility assessment (5 items), predictive modeling (5 items), and integration with fundamentals (5 items). Each item presented students with financial time series data and required them to analyze specific aspects, identify patterns, or make predictions based on the data. The assessment underwent validation through expert review by three financial analysts and two educational measurement specialists, followed by pilot testing with a separate cohort of finance students. Reliability analysis yielded a Cronbach's alpha of 0.86 for the overall instrument, with component-specific reliability coefficients ranging from 0.78 to 0.89.

The Stock Market Game platform itself functioned as a data collection instrument through its built-in analytics module, which captured detailed metrics on student engagement and performance. The system automatically recorded quantitative indicators including frequency of tool usage (counts of specific analytical features accessed), time spent on analysis (minutes per session), trading patterns (frequency, timing, and types of transactions), portfolio performance (returns relative to market benchmark), and prediction accuracy (alignment between stated forecasts and actual market movements). This automated data collection occurred continuously throughout the 10-week intervention, generating longitudinal datasets for each participant. The platform architecture employed industry-standard security protocols to ensure data integrity while allowing instructors and researchers to access anonymized performance metrics through a password-protected dashboard.

A mixed-methods Student Reflection Journal completed weekly by all participants complemented the quantitative instruments. This semi-structured template prompted students to document their analytical processes, explain the rationale behind trading decisions, evaluate strategy effectiveness, and identify challenges encountered during analysis. The journal included both Likert-scale items assessing self-perceived competency in specific skills and open-ended questions encouraging reflection on learning processes. Content analysis of these journals used a coding framework developed through thematic analysis of pilot responses, with two independent raters achieving an inter-rater reliability coefficient of 0.83. This instrument captured qualitative dimensions of students' analytical development that might not be evident in performance metrics alone, including metacognitive awareness, strategy evolution, and conceptual understanding of time series principles.

Data Collection Process

Data collection proceeded through a three-phase process following approval from the Ethics Committee of Estrategia y Datos LLC (approval code: EDL-2022-048). The pre-intervention phase established baseline competency levels through administration of the Financial Time Series Analysis Assessment (FTSAA) during orientation sessions held in university computer labs. Students completed this 90-minute assessment under supervised conditions, with responses automatically captured through the secure testing platform. Demographic information and prior academic performance metrics were obtained from institutional records with appropriate student consent, ensuring comprehensive background data for subsequent analysis of learning patterns.

Throughout the 10-week intervention, the Stock Market Game platform continuously collected engagement and performance data. The platform's analytics module, customized for educational research through funding from Education for All Online under grant 15-42-2285-30, captured detailed metrics on student interaction with analytical tools, time allocation across activities, and decision-making patterns. This automated data collection system employed advanced logging mechanisms that preserved user privacy while generating granular insights into learning behaviors. Weekly Student Reflection Journals were completed during the last 20 minutes of Friday class sessions, with responses submitted through the course management system and automatically linked to corresponding performance data.

Results

Split-Half Reliability Testing

The second data validation procedure involved split-half reliability testing to assess the internal consistency of the assessment instruments. The pre-test and post-test items were divided into two equivalent halves using an odd-even allocation method, and student performance was calculated for each half. This approach tested whether the instruments consistently measured the same underlying constructs across different items, ensuring that observed changes in performance could be attributed to actual learning rather than measurement inconsistency.

Table 7: Split-Half Reliability Testing Results.

Assessment Component	First Half Mean	Second Half Mean	Pearson Correlation	Spearman-Brown Coefficient	95% Confidence Interval	Interpretation
Pre-test Overall	64.7	63.9	0.78	0.88	[0.82, 0.93]	High reliability
Pattern Recognition	61.5	60.9	0.72	0.84	[0.76, 0.90]	Good reliability
Trend Analysis	67.8	67.2	0.75	0.86	[0.79, 0.91]	Good reliability

Seasonal Adjustment	58.7	58.1	0.69	0.82	[0.73, 0.88]	Good reliability
Volatility Assessment	64.1	63.5	0.70	0.82	[0.74, 0.89]	Good reliability
Predictive Modeling	70.6	69.8	0.73	0.84	[0.77, 0.90]	Good reliability
Integration with Fundamentals	65.5	64.5	0.71	0.83	[0.75, 0.89]	Good reliability
Post-test Overall	78.9	78.3	0.82	0.90	[0.85, 0.94]	High reliability

At the component level, all skill areas showed good to high reliability, with Spearman-Brown coefficients ranging from 0.82 to 0.86. The pattern recognition component yielded a coefficient of 0.84, indicating that items measuring this skill consistently assessed the same underlying construct. Similarly, trend analysis (0.86), seasonal adjustment (0.82), volatility assessment (0.82), predictive modeling (0.84), and integration with fundamentals (0.83) all demonstrated robust internal consistency. These findings establish that each skill component was measured reliably, allowing for meaningful interpretation of pre-post changes at both the overall and component-specific levels.

The similar means between first and second halves across all components (with differences ranging from 0.6 to 1.0 points) further support the equivalence of the split halves. The comparable Pearson correlations across components (ranging from 0.69 to 0.78 for pre-test components) indicate that the instruments maintained consistent measurement properties across different skill areas. The slightly higher correlation and reliability coefficients for the post-test (0.82 and 0.90, respectively) compared to the pre-test (0.78 and 0.88) suggest that student responses became somewhat more consistent after the intervention, possibly reflecting more coherent understanding of financial time series analysis concepts.

Hypothesis Testing Procedures

Paired Samples Permutation Test

The test involved calculating the mean difference between pre-test and post-test scores as the test statistic, then randomly reassigning pre/post labels 10,000 times to generate a null distribution. If the actual test statistic fell outside the central 95% of this permutation distribution, the null hypothesis of no improvement was rejected.

Table 8: Paired Samples Permutation Test Results.

Skill Component	Pre-test Mean	Post-test Mean	Mean Difference	Empirical p-value	95% CI for Difference	Effect Size (Cohen's d)	Statistical Decision
Overall Score	64.3	78.6	+14.3	0.0026	[10.8, 17.8]	0.97	Reject H_0
Pattern Recognition	61.2	79.8	+18.6	0.0014	[14.5, 22.7]	1.24	Reject H_0
Trend Analysis	67.5	82.3	+14.8	0.0031	[11.2, 18.4]	0.96	Reject H_0
Seasonal Adjustment	58.4	75.6	+17.2	0.0018	[13.1, 21.3]	1.15	Reject H_0

Volatility Assessment	63.8	72.9	+9.1	0.0238	[4.9, 13.3]	0.62	Reject H ₀
Predictive Modeling	70.2	77.3	+7.1	0.0329	[2.8, 11.4]	0.45	Reject H ₀
Integration with Fundamentals	65.0	83.5	+18.5	0.0015	[14.3, 22.7]	1.22	Reject H ₀

The paired samples permutation test yielded strong evidence supporting the primary hypothesis that the Stock Market Game intervention improved students' financial time series analysis competency. The overall mean difference between pre-test and post-test scores was 14.3 points, with an empirical p-value of 0.0026, well below the conventional threshold of 0.05. This result indicates that the observed improvement was unlikely to occur by chance, with less than 1% of random permutations producing a difference as large as or larger than the actual difference. The 95% confidence interval for this difference [10.8, 17.8] does not include zero, further supporting the conclusion that a genuine improvement occurred.

The skill-specific results revealed varying magnitudes of improvement across different components of financial time series analysis. Pattern recognition showed the largest mean improvement (+18.6 points, $p = 0.0014$), closely followed by integration with fundamentals (+18.5 points, $p = 0.0015$) and seasonal adjustment (+17.2 points, $p = 0.0018$). These three components all exhibited large effect sizes (Cohen's $d > 1.0$), indicating substantial practical significance beyond statistical significance. Trend analysis showed a moderate-to-large improvement (+14.8 points, $p = 0.0031$, $d = 0.96$), suggesting that students developed considerably enhanced abilities to identify directional movements in financial data.

The particularly large improvements in pattern recognition and integration with fundamentals suggest that the game was especially effective at developing students' abilities to identify recurring patterns in financial data and connect price movements with underlying economic factors—two skills with high practical relevance for financial decision-making.

Hierarchical Linear Modeling

Hierarchical Linear Modeling (HLM) was employed to examine learning trajectories over the ten-week intervention period and identify factors that influenced the rate of improvement. This analytical approach was selected because it accounts for the nested structure of the data, with multiple time points (level 1) nested within individual students (level 2). The model included time as a level-1 predictor and student characteristics (prior finance coursework, self-reported comfort with technology, and baseline performance) as level-2 predictors. This approach allowed for the examination of both average growth trajectories and individual differences in learning rates.

Table 9: Hierarchical Linear Modeling Results for Weekly Performance Growth.

Fixed Effects						
Parameter	Coefficient	Standard Error	t-value	p-value	95% CI	
Intercept (Week 1 performance)	54.21	2.34	23.17	<0.001	[49.62, 58.80]	

Time (weekly growth)	3.12	0.41	7.61	<0.001	[2.32, 3.92]
Time ² (acceleration/deceleration)	-0.18	0.04	-4.50	<0.001	[-0.26, -0.10]
Prior finance coursework	2.85	1.23	2.32	0.026	[0.44, 5.26]
Technology comfort	1.74	0.97	1.79	0.081	[-0.16, 3.64]
Baseline performance	0.32	0.10	3.20	0.003	[0.12, 0.52]
Prior finance × Time	0.35	0.16	2.19	0.033	[0.04, 0.66]
Technology comfort × Time	0.43	0.13	3.31	0.002	[0.18, 0.68]
Baseline performance × Time	-0.04	0.01	-4.00	<0.001	[-0.06, -0.02]
Random Effects					
Effect	Variance	SD	χ^2	p-value	
Intercept	42.89	6.55	183.42	<0.001	
Time slope	0.85	0.92	98.63	<0.001	
Level-1 residual	23.74	4.87	-	-	
Model Fit Statistics					
Statistic	Value				
Deviance	2348.76				
AIC (Akaike Information Criterion)	2370.76				
BIC (Bayesian Information Criterion)	2412.53				
Intraclass Correlation (ICC)	0.64				

Several student-level characteristics influenced both initial performance and growth trajectories. Prior finance coursework was associated with higher initial performance ($\beta = 2.85$, $p = 0.026$) and slightly faster improvement over time ($\beta = 0.35$, $p = 0.033$). Similarly, comfort with technology showed a positive but marginally significant relationship with initial performance ($\beta = 1.74$, $p = 0.081$) but a clearly significant positive effect on the rate of improvement ($\beta = 0.43$, $p = 0.002$). These findings suggest that prior financial knowledge gave students a head start, while technological fluency primarily accelerated their learning process during the game-based intervention.

Baseline performance showed a complex relationship with learning trajectories. Higher baseline scores predicted higher initial game performance ($\beta = 0.32$, $p = 0.003$) but slower rates of improvement over time ($\beta = -0.04$, $p < 0.001$). This negative interaction between baseline performance and growth rate aligns with the ceiling effect observed in the quartile analysis, where students who began with higher competency levels had less room for improvement. The significant random effects for both intercept ($\chi^2 = 183.42$, $p < 0.001$) and time slope ($\chi^2 = 98.63$, $p < 0.001$) indicate substantial individual differences in both starting points and growth rates that were not fully explained by the included predictors, suggesting other personal factors may have influenced learning trajectories.

Quantile Regression Analysis

Quantile regression analysis was conducted to examine intervention effects across different performance levels rather than focusing solely on mean effects. This statistical procedure estimates the relationship between variables at different points in the conditional distribution of the dependent variable. By comparing coefficients across the 25th, 50th, and 75th percentiles, this approach determined whether the Stock Market Game benefited students differently depending on their position in the performance distribution. This analysis directly addressed questions about the equity of the intervention's impact across different student groups.

Table 5: Quantile Regression Results for Pre-Post Improvement.

Quantile Regression Results						
Predictor Variable	25th Percentile	50th Percentile (Median)		75th Percentile		
	Coefficient	Standard Error	p-value	Coefficient	Standard Error	p-value
Intercept	35.67	8.23	<0.001	28.41	6.81	<0.001
Pre-test score	-0.48	0.13	<0.001	-0.32	0.11	0.006
Prior finance coursework	2.84	1.31	0.037	2.56	1.18	0.038
Technology comfort	2.63	1.04	0.016	2.32	0.93	0.018
Hours spent in game	0.73	0.21	0.001	0.68	0.19	0.001
Tool usage variety	2.82	0.86	0.002	2.41	0.77	0.004
Model Statistics						
Statistic	25th Percentile	50th Percentile (Median)	75th Percentile			
Pseudo R ²	0.43	0.39	0.32			

Mean Error (MAE)	Absolute 4.28	3.96	4.52
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The quantile regression analysis revealed that the impact of the Stock Market Game intervention varied across different segments of the performance distribution, with generally stronger effects for lower-performing students. At the 25th percentile, each unit increase in pre-test score was associated with a 0.48-point decrease in improvement ($p < 0.001$), compared to a 0.32-point decrease at the median ($p = 0.006$) and a marginally significant 0.23-point decrease at the 75th percentile ($p = 0.058$). This pattern indicates that the negative relationship between initial performance and improvement magnitude was strongest for students in the lower portion of the distribution, confirming that the intervention had a particularly strong equalizing effect for students who began with lower competency levels.

Prior finance coursework showed a consistent positive effect on improvement at the 25th percentile ($\beta = 2.84$, $p = 0.037$) and median ($\beta = 2.56$, $p = 0.038$), but the effect became non-significant at the 75th percentile ($\beta = 1.78$, $p = 0.192$). This pattern suggests that prior financial knowledge enhanced the benefits of the game-based intervention primarily for lower and middle-performing students, while top performers benefited similarly regardless of prior coursework.

This pattern directly answers the research question by indicating that the game-based approach not only improves competency overall but does so in a way that promotes educational equity by providing the largest benefits to students who begin with the greatest needs. The declining Pseudo R^2 values from the 25th percentile (0.43) to the 75th percentile (0.32) further suggest that the measured predictors explain more variation in improvement for lower-performing students, potentially because higher-performing students' outcomes depend more on unmeasured factors such as intrinsic motivation or specific learning strategies.

Implications for Educational Practice in Financial Analysis Training

The findings from this study offer a measured perspective on how game-based learning approaches may influence the development of financial time series analysis skills in undergraduate business students. The data suggest that the Stock Market Game created a learning environment where students could practice analytical techniques in a context that approximated real-world financial decision-making. The considerable improvements across all measured skill components—with pattern recognition, integration with fundamentals, and seasonal adjustment showing the strongest gains—point to the potential value of experiential learning for complex quantitative competencies that traditionally present challenges in conventional classroom settings.

What appears most noteworthy is the differential impact across the student performance spectrum. The quantile regression results indicate that students who began with lower competency levels experienced more substantial improvements than their higher-performing peers. This pattern suggests that game-based approaches might help address educational equity concerns by offering additional benefits to students who enter with knowledge gaps. However, the modest improvements in more advanced skills like volatility assessment and predictive modeling remind us that game-based learning has limitations, particularly for developing sophisticated analytical capabilities that may require more structured instruction. The trajectory analysis through hierarchical linear modeling adds temporal context to these findings, showing that improvement rates accelerated during the middle weeks of the intervention before gradually plateauing. This pattern resembles learning curves documented in other skill acquisition contexts, suggesting that financial analysis competency development follows similar principles. The influence of prior finance coursework and technology comfort on learning trajectories highlights how personal characteristics shape educational outcomes, even within standardized interventions. These factors must be considered when implementing similar approaches in diverse student populations.

The correlation between game engagement metrics and post-test performance offers practical implications for educators. Students who actively utilized time series analysis tools, maintained strategy

consistency, and dedicated more time to analysis showed greater improvements than those who traded frequently without analytical depth. This finding suggests that the educational value of simulation games depends not just on participation but on how students engage with the platform. Course designs should include structures that encourage thoughtful analysis rather than merely rewarding transaction volume or financial returns within the game.

Discussion

The results of this study expanded current understanding of how game-based learning approaches influenced the development of specialized financial competencies among undergraduate business students. The findings confirmed that the Stock Market Game positively impacted financial time series analysis skills, with particularly strong effects on pattern recognition, integration with fundamentals, and seasonal adjustment components. These results aligned with Cannistrà et al. (2024), who documented similar positive outcomes for general financial literacy through game-based interventions across multiple countries. However, this study advanced knowledge by disaggregating financial analysis competency into specific subskills and measuring differential impacts across these components—a level of granularity absent from many prior investigations.

The hierarchical linear modeling results, which showed initial rapid improvement followed by more gradual gains, complemented theoretical frameworks presented by Wilson et al. (2020) regarding learning trajectories in game-based educational environments. The decelerating improvement curve observed in this study suggested that financial analysis skill development followed patterns similar to other complex competencies, with diminishing returns as students approached higher performance levels. This finding added empirical support to Wilson's theoretical model while offering specific context for financial education. The differential impacts across student subgroups, with lower-performing students showing larger gains, echoed Kaur et al. (2024), who found that gamified financial education had heterogeneous effects based on initial competency levels.

Regarding the relationship between engagement metrics and learning outcomes, this study found that time spent on analysis and tool usage frequency correlated moderately with performance improvement. These findings paralleled Lai's (2022) work on cognitive engagement in digital game-based learning but added specificity regarding which forms of engagement most effectively promoted financial analysis skills. Notably, the weak correlation between trading frequency and performance improvement challenged assumptions that activity volume necessarily indicated productive engagement. Instead, the results suggested that thoughtful, tool-supported analysis rather than rapid trading better developed analytical competencies—a distinction not emphasized in prior literature.

The primary research question concerning the extent to which the Stock Market Game improved financial time series analysis competency received a clear answer: students showed statistically meaningful improvement across all skill components with moderate to large effect sizes for most components. The paired samples permutation test confirmed the statistical validity of these improvements, while the quantile regression analysis added important nuance by demonstrating larger effects for initially lower-performing students. This addressed both the general research objective of evaluating the game's effectiveness and the specific objective of comparing performance evolution before and after the intervention. The pattern of results supported the hypothesis that game-based learning improved financial analysis competency while revealing important variations in impact across skill components and student subgroups.

Limitations and Future Research

Despite these valuable findings, several limitations affected the study's generalizability and interpretive scope. First, the relatively small sample size (38 students, reduced to 36 after outlier removal) from a single

institution limited statistical power and restricted external validity. Future research should include larger, more diverse samples across multiple institutions and educational contexts. Second, the single-group pretest-posttest design without a control group made it difficult to isolate the specific effects of the Stock Market Game from other factors that might have influenced learning during the study period. Subsequent studies would benefit from experimental or quasi-experimental designs with appropriate control or comparison groups.

The 10-week intervention timeframe, while practical within academic semester constraints, may have been insufficient for developing more advanced skills like volatility assessment and predictive modeling, which showed smaller improvements. Future studies could implement longer interventions or longitudinal follow-up assessments to examine skill retention and continued development over time. Additionally, while the quantitative findings documented improvements in analysis skills, the study offered limited insight into the cognitive processes underlying these improvements. Incorporating more qualitative methods, such as think-aloud protocols during game play or detailed cognitive interviews, could help clarify how students developed specific analytical strategies.

The investigation focused primarily on skill development rather than knowledge transfer to real-world financial analysis contexts. Future research should assess whether improved game performance translated to better decision-making with actual financial data. Additionally, the study did not systematically explore how different game design elements contributed to learning outcomes. Future work could employ experimental manipulation of specific game features to identify which elements most effectively supported financial analysis skill development.

The correlation between engagement metrics and learning outcomes suggested promising avenues for future research but fell short of establishing causal relationships. More sophisticated research designs, perhaps incorporating randomized encouragement of different engagement patterns, could help determine whether specific behaviors like increased tool usage directly caused improved learning or merely indicated higher motivation levels. Furthermore, while student characteristics like prior finance coursework and technology comfort influenced learning trajectories, the study did not exhaustively explore individual difference factors. Future research could investigate how learning styles, metacognitive abilities, and epistemic beliefs moderated the relationship between game-based learning and financial analysis skill development.

Methodologically, while the study employed relatively sophisticated analytical techniques like hierarchical linear modeling and quantile regression, alternative approaches such as structural equation modeling or growth mixture modeling could further illuminate the complex relationships between student characteristics, engagement patterns, and learning outcomes. Such approaches might better capture the multidimensional nature of financial analysis competency development. Additionally, future studies should consider including physiological or neurological measures to assess cognitive load and engagement during gameplay, potentially offering insight into the attentional and emotional mechanisms underlying effective learning in game-based environments.

Conclusion

This study evaluated the effectiveness of the Stock Market Game for developing financial time series analysis competency among business administration students at UNIMINUTO Barranquilla. The findings confirmed that students experienced substantial improvement across all measured analytical skills, with particularly strong gains in pattern recognition (+18.6 points), integration with fundamentals (+18.5 points), and seasonal adjustment (+17.2 points). Statistical validation through paired samples permutation testing, hierarchical linear modeling, and quantile regression analysis established that these improvements were unlikely to occur by chance and followed learning trajectories consistent with skill acquisition theory. The differential impact across performance quartiles, with lower-performing students showing larger

gains, suggested that game-based approaches may help address educational equity concerns in quantitative business education.

The results carried practical implications for financial education while highlighting areas for future research. The moderate correlations between engagement metrics and learning outcomes indicated that thoughtful analysis and tool usage were more important than trading frequency for developing analytical competencies. Course designs incorporating the Stock Market Game should therefore encourage depth of analysis rather than volume of transactions. While the 10-week intervention successfully improved most skill components, the smaller gains in advanced skills like volatility assessment and predictive modeling suggested that longer interventions or supplementary instructional approaches might be necessary for these complex competencies. Future studies using experimental designs with control groups across multiple institutions would help establish the generalizability of these findings and clarify how game-based approaches can best complement traditional financial education methods.

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Appendix A: Financial Time Series Analysis Learning Experience Survey.

Introduction

Thank you for participating in this survey about your learning experience with the Stock Market Game. Your thoughtful responses will help us understand how this educational approach influenced your financial analysis skills and what aspects were most beneficial to your learning. This survey is part of a research project funded by Education for All Online (grant 15-42-2285-30) and has been approved by the Ethics Committee of Estrategia y Datos LLC. Your responses will remain confidential and will only be used for research purposes. The survey should take approximately 15-20 minutes to complete. Please answer all questions honestly based on your personal experience.

Survey Questions

Section 1: Overall Learning Experience

1. *How would you rate your overall experience with the Stock Market Game as a learning tool?*
 - *Excellent*
 - *Very Good*
 - *Good*
 - *Fair*
 - *Poor*
2. *How would you rate your confidence in financial time series analysis before participating in this course?*
 - *Very confident*
 - *Somewhat confident*
 - *Neutral*
 - *Somewhat unconfident*
 - *Very unconfident*
3. *How would you rate your confidence in financial time series analysis after participating in this course?*
 - *Very confident*
 - *Somewhat confident*
 - *Neutral*
 - *Somewhat unconfident*

- *Very unconfident*
- 4. *Which aspects of the Stock Market Game did you find most helpful for developing your analytical skills? (Select up to three)*
- *Historical data visualization tools*
- *Pattern recognition exercises*
- *Peer collaboration opportunities*
- *Instructor coaching sessions*
- *Weekly challenges*
- *Performance feedback*
- *Reflection activities*
- *Competitive elements*

Section 2: Skill Development

5. *For each analytical skill below, please rate how much you believe the Stock Market Game helped you improve:*
Pattern Recognition

- *Greatly improved*
- *Somewhat improved*
- *No change*
- *Somewhat declined*
- *Greatly declined*

Trend Analysis

- *Greatly improved*
- *Somewhat improved*
- *No change*
- *Somewhat declined*
- *Greatly declined*

Seasonal Adjustment

- *Greatly improved*
- *Somewhat improved*
- *No change*
- *Somewhat declined*
- *Greatly declined*

Volatility Assessment

- *Greatly improved*
- *Somewhat improved*
- *No change*
- *Somewhat declined*

- Greatly declined

Predictive Modeling

- Greatly improved
- Somewhat improved
- No change
- Somewhat declined
- Greatly declined

Integration with Fundamentals

- Greatly improved
- Somewhat improved
- No change
- Somewhat declined
- Greatly declined

6. Please describe a specific example where you successfully applied time series analysis techniques to make a trading decision in the game: [Open text response]
7. What was the most challenging aspect of financial time series analysis for you, and did the game help you overcome this challenge? How? [Open text response]

Section 3: Learning Process

8. On average, how many hours per week did you spend engaging with the Stock Market Game outside of class time?
 - Less than 1 hour
 - 1-2 hours
 - 3-4 hours
 - 5-6 hours
 - More than 6 hours
9. Which analytical tools did you use most frequently? (Select all that apply)
 - Moving averages
 - Relative strength indicators
 - Bollinger bands
 - MACD indicators
 - Seasonal decomposition
 - Volatility measures
 - Regression analysis
 - Other: [please specify]
10. How frequently did you collaborate with peers on analysis strategies?
 - Very frequently
 - Frequently

- *Occasionally*
- *Rarely*
- *Never*

11. *How helpful were the weekly reflection activities for developing your analytical skills?*

- *Very helpful*
- *Somewhat helpful*
- *Neutral*
- *Somewhat unhelpful*
- *Very unhelpful*

12. *How did your approach to time series analysis change from the beginning to the end of the course? [Open text response]*

Section 4: Comparison to Traditional Learning

13. *Compared to traditional lecture-based learning, how effective was the Stock Market Game for developing your financial analysis skills?*

- *Much more effective*
- *Somewhat more effective*
- *About the same*
- *Somewhat less effective*
- *Much less effective*

14. *Please explain your answer to the previous question: [Open text response]*

15. *How likely are you to apply the analytical skills developed through this course in your future academic or professional work?*

- *Very likely*
- *Somewhat likely*
- *Neutral*
- *Somewhat unlikely*
- *Very unlikely*

Section 5: Suggestions for Improvement

16. *What aspects of the Stock Market Game could be improved to better develop financial time series analysis skills? [Open text response]*

17. *What additional resources or support would have enhanced your learning experience? [Open text response]*

18. *Would you recommend this approach for teaching financial time series analysis to future students? Why or why not? [Open text response]*

Conclusion and Thanks

Thank you for completing this survey about your experience with the Stock Market Game. Your feedback is invaluable for enhancing this educational approach and understanding its effectiveness for developing financial time series analysis skills. The information you've shared will help improve the learning experience for future students and contribute to research on innovative teaching methods in business education.