Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

MATHEMATICAL FINANCE

MASTERS FINAL WORK

PROJECT

PROPOSING A MARKET SIMULATION GAME

AFONSO MARIA CORREIA DE ARAÚJO CAPELO

12 - 2024

Lisbon School of Economics & Management
Universidade de Lisboa

MASTER
MATHEMATICAL FINANCE

MASTERS FINAL WORK
PROJECT

PROPOSING A MARKET SIMULATION GAME

AFONSO MARIA CORREIA DE ARAÚJO CAPELO

SUPERVISOR:
PROF. CARLOS J. COSTA

JURY:

PRESIDENT - Prof. João Janela
MEMBER - Prof. Flávio Costa Romão
SUPERVISOR - Prof. Carlos J. Costa

12 - 2024


ISEG
Lisbon School
of Economics
& Management
Universidade de Lisboa

GLOSSARY

NIG - Normal Inverse Gaussian

JEL - Journal of Economic Literature

OECD - Organisation for Economic Co-operation and Development

RAND - Research and Development

SMG - Stock Market Game

DSR - Design Science Research

HTML - HyperText Markup Language

CSS - Cascading Style Sheets

exp – Exponential Function

ABSTRACT

Financial literacy is critical for personal empowerment and economic stability. However, traditional financial education methods often fail to bridge the gap between theoretical knowledge and practical application, leaving many individuals unprepared to make informed financial decisions in increasingly complex economic systems.

This Master's Final Work investigates the potential of serious games as an innovative tool to enhance financial literacy. Specifically, it aims to design and evaluate a stock market simulation game that immerses players in a dynamic market environment while introducing essential financial concepts.

The study adopts a Design Science approach, focusing on the development of an artifact—a serious game—based on mathematical concepts such as the Normal Inverse Gaussian (NIG) process. This artifact simulates realistic stock price fluctuations, stochastic processes, and ambiguous market events. The game mechanics are carefully designed to align with educational objectives, encouraging critical thinking, strategic planning, and decision-making under uncertainty.

The proposed game introduces players to key financial concepts, including risk and reward, diversification, and decision-making under uncertainty. Players can experiment with investment strategies, analyze market dynamics, and refine their financial decision-making skills by providing a risk-free, interactive environment. The simulation fosters engagement and competence, addressing common barriers to understanding complex financial topics.

This study demonstrates that serious games, like the developed stock market simulation, can effectively bridge the gap between theoretical financial knowledge and practical application. By using a design science methodology and mathematical modeling, the game serves as an accessible, engaging, and impactful educational tool that empowers individuals to navigate financial markets with confidence.

KEYWORDS: Financial literacy, serious games, stock market simulation, Normal Inverse Gaussian process, Design Science, financial education, decision-making.

Lisbon School of Economics & Management
Universidade de Lisboa

TABLE OF CONTENTS

Lisbon School of Economics & Management
Universidade de Lisboa

LIST OF FIGURES

Lisbon School of Economics & Management
Universidade de Lisboa

LIST OF TABLES

Lisbon School of Economics & Management
Universidade de Lisboa

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my supervisor, Prof. Carlos J. Costa, for his exceptional mentorship and guidance throughout my master's journey. Professor Costa has been an unwavering source of support and inspiration, and his insightful contributions have profoundly shaped the development of this thesis. His expertise, patience, and dedication to my academic growth have not only helped me improve my research but also motivated me to challenge myself and expand my knowledge. His constructive feedback, critical thinking, and commitment to excellence were invaluable in overcoming the challenges I faced during this process. I am incredibly fortunate to have had the opportunity to work with such a remarkable academic and mentor. I will forever cherish the knowledge and experience gained under his mentorship.

To my family, I am forever indebted for your love, patience, and sacrifices. A special thanks to my mother, father, and brother, whose support has been my foundation throughout this journey. To my mother, whose boundless love and nurturing spirit have always guided me; to my father, whose wisdom and thoughtful advice have kept me grounded and focused; and to my brother, whose companionship and encouragement have been a constant source of joy and strength, I am beyond grateful. Your belief in me has been the greatest motivator.

I want to thank my friends for their unwavering support and understanding during this challenging yet rewarding journey. Your constant encouragement, patience, and humor have been a much-needed source of strength, especially in the toughest moments. I am grateful for the countless moments of laughter, for always being there to listen, and for believing in me. Your friendship has been a true gift, and I am lucky to have you in my life.

Lastly, I would like to acknowledge the use of Generative AI tools, such as ChatGPT, to refine the language and clarity of this thesis. All intellectual contributions and research content remain my own.

1. INTRODUCTION

In an era of increasing financial complexity, financial literacy has emerged as a crucial skill for fostering individual empowerment and societal economic stability (Kumari, 2020; Lusardi, 2019). Despite its importance, traditional financial education methods often fail to bridge the gap between theoretical understanding and practical application (Gallery & Gallery, 2010; Adams & Rau, 2011). This gap highlights the need for innovative and engaging tools that make financial education accessible, interactive, and effective.

This thesis explores the potential of serious games as a novel approach to enhancing financial literacy. Specifically, it examines a stock market simulation game that immerses players in a dynamic market environment. The framework of the game is built on a robust mathematical foundation, utilizing the Normal Inverse Gaussian (NIG) process.

The motivation for this study stems from the increasing recognition that financial literacy is critical for informed decision-making in modern economic systems. However, many individuals find financial concepts intimidating or inaccessible, hindering their participation in investment activities. By leveraging the engaging nature of serious games, this thesis seeks to address these barriers, fostering confidence and competence in financial decision-making.

The focus of this study is to evaluate the educational potential of a stock market simulation game designed to promote financial literacy. The game immerses players in fluctuating stock prices, influenced by stochastic processes and ambiguous events, creating a dynamic and unpredictable environment. The primary objectives of the study are to introduce key financial concepts such as risk, reward, and diversification, encourage critical thinking and strategic decision-making under uncertainty, and build confidence in financial decision-making by providing an interactive, realistic learning experience. These objectives will guide the design of the game and form the basis for evaluating its educational effectiveness

To achieve this, the methodology combines mathematical modeling with educational game principles. The NIG process provides the mathematical framework for realistic stock price simulations, while event-driven mechanics enrich the gameplay experience by simulating unpredictable market influences. Players are encouraged to analyze events

and their descriptions, assess potential impacts, and refine their strategies, promoting critical thinking and strategic planning. The risk-free nature of the simulation enables participants to experiment with various investment strategies and learn from their outcomes without incurring real financial consequences.

This project argues that the proposed stock market simulation game represents a novel, engaging, and effective tool for financial education. By combining rigorous mathematical modeling with interactive gameplay, the game seeks to empower individuals with the knowledge and skills to navigate the complexities of financial markets. The findings demonstrate how serious games can serve as a powerful medium for enhancing financial literacy, bridging the gap between theory and practice in an accessible and impactful way.

2. Literature Review

The Importance of Financial Literacy

In a world where financial decisions impact nearly every aspect of life, understanding and managing personal finances has become crucial. With an ever-growing range of investment options and economic challenges, individuals need the skills to navigate these complexities and secure financial wellbeing.

It is important to discuss the concept of financial literacy, which is crucial for young people to navigate the complexities of modern financial systems.

Over the past few years, financial literacy has gained significant attention from scholars, financial institutions, and policymakers (Kumari, 2017; Lusardi, 2019). According to Cole and Fernando (2008), financial literacy is the ability to process financial information and make informed decisions about personal finance. Another definition of financial literacy was given by Kumari (2020), which states that financial literacy is the possession of knowledge and skills that enable informed and effective money management.

Financial Literacy and Its Influence on Investment Decisions

Kumari (2020) investigated the impact of financial literacy on investment decisions among 200 university undergraduates from four government universities in the Western Province of Sri Lanka, suggesting that financial skills are crucial for enhancing investment decisions among undergraduates.

The study by Gallery et al. (2011) builds upon previous research by focusing on financial literacy measures that are directly relevant to retirement investment decisions. Studies suggest that individuals with higher financial literacy tend to have greater disposable income and an enhanced ability to "spend, save, and invest" effectively (Garman, 1997).

Capuano and Ramsay (2011) explain that financial literacy enables individuals to utilize financial products more efficiently, avoiding unnecessary costs and making smarter investment decisions. Those who are financially literate often have more disposable income, a greater ability to save, and are typically more productive investors (Cole & Fernando, 2008).

Recent literature has reached the connection between retirement outcomes and financial literacy. For instance, Lusardi and Mitchell (2007a, 2007b, 2008) extensive work using various U.S. data sources emphasizes that financial literacy is crucial for effective retirement planning and preparation.

In contrast, research by Hung, Yoong, and Brown (2012), utilizing RAND American Life Panel data, examined the relationship between financial literacy and several factors related to retirement savings accounts. Their findings support a positive correlation between financial literacy and the extent to which individuals have considered their retirement.

Mahdzan and Tabiani (2013) argue that enhancing financial literacy and competence improves financial decision-making, facilitating better planning and management of life events such as education, home buying, and retirement.

Financial Literacy and Market Participation

Research consistently shows a strong positive relationship between financial literacy and participation in financial markets. Financially literate individuals are more likely to invest in stocks, bonds, and other financial products due to their ability to evaluate risks and returns, face fewer barriers to entry, and manage lower transaction costs. For example, Van Rooij et al. (2011) found that financially literate individuals in the Netherlands were more likely to invest in stocks, while Yoong (2011), Thomas and Spataro (2018) reported similar findings among older Americans and across European countries, respectively.

Financial literacy can foster broader market participation, enhance household wealth, and contribute to economic growth. Studies by Behrman et al. (2012) and Guiso and Jappelli (2005) emphasize that a lack of financial knowledge limits market involvement. In contrast, financially literate individuals tend to diversify their investments and avoid inefficient financial decisions, such as unfavorable mortgages or poor savings management (Fratantoni, 1998).

According to Khan, Rabbani, and Kadoya (2020), financially literate individuals are more likely to invest in various financial products such as stocks, bonds, and foreign currency deposits. It is also suggested that increasing financial literacy could boost investment in financial markets, benefit' household wealth, and contribute to acountry's sustainable

development by promoting capital accumulation for economic growth.

Promoting financial literacy has significant implications for individual financial wellbeing and broader economic development.

The Widespread Challenge of Financial Illiteracy

Low levels of financial knowledge have been observed in numerous countries. For instance, the OECD (2005) highlighted that financial illiteracy is prevalent across many developed countries (Christelis, Jappelli, & Padula, 2010).

In the U.S., Lusardi and Mitchell (2011) found that financial literacy is particularly low among young people, women, and those with lower education levels. Van Rooij, Lusardi, and Alessie (2011) demonstrated that financial literacy influences financial decision-making, noting that individuals with lower literacy are significantly less likely to invest in stocks. Lusardi, Mitchell, and Curto (2010) also studied financial literacy among young adults and found that fewer than one-third possess basic knowledge of key financial concepts like interest rates, inflation, and risk diversification.

Capuano and Ramsay (2011) reviewed 23 financial literacy surveys, including those from the World Bank and various countries. Their findings indicate that participants in these surveys generally showed poor financial knowledge and awareness.

The Importance of Financial Literacy

Enhancing financial literacy through educational initiatives has become a pressing concern, as the lack of financial knowledge was identified as a contributing factor to the global financial crisis (Gallery & Gallery, 2010). Governments increasingly recognize the importance of equipping individuals with adequate financial skills and knowledge. However, research on financial literacy, both in the general population and specific subgroups, reveals that financial illiteracy is pervasive (OECD, 2005).

While early studies on workplace financial education programs, such as those by Rai (2019) and Bernheim and Garrett (2003), found that financial literacy plays a crucial role in promoting healthy financial behaviors, more recent literature reviews offer differing perspectives on the impact of financial literacy and education (Adams & Rau, 2011; Willis, 2008). Specifically, Adams and Rau (2011) assert that "both experimental and

non-experimental studies demonstrate that understanding fundamental saving principles, such as compound interest, directly influences financial preparedness, even after accounting for demographic factors."

Serious Games: Redefining Financial Education

In today's complex financial landscape, equipping people with the skills to navigate financial challenges is more important than ever. However, traditional financial education methods often fail to engage and motivate this audience. As a result, there is a growing interest in leveraging innovative tools to make learning about finance effective and enjoyable.

One such tool is serious games, which are (digital) games that do not have entertainment, enjoyment, or fun as their primary purpose, as reported by Laamarti, Eid, and El Saddik (2014).

Following the same idea, an overview of Serious Games was also addressed by Susi, Johannesson, and Backlund (2007), leading to the concept of these games that are specifically designed to fulfill objectives beyond just amusement, encompassing areas such as training, advertising, simulation, and education. Serious games are tailored to personal computers or video game consoles, providing an engaging learning and skill development platform (Costa & Costa, 2011; Sousa & Costa, 2011, Costa, 2025).

In other words, game-based learning or serious games " is all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills" (Corti, 2006).

The Educational Value of Serious Games

Serious games are designed to have a meaningful impact beyond entertainment, particularly in education, where they hold great potential for enhancing learning experiences (Aparicio & Costa, 1999; Gee, 2007; Greitzer, Kuchar, & Huston, 2007). These games aim to be fun and educational, appealing to a broad audience while meeting specific learning goals (De Grove, Mechant, & Van Looy, 2010; Van Eck, 2006). Assessing serious games involves evaluating enjoyment and educational effectiveness, which presents unique challenges since learning is the primary objective.

The educational potential of video games is widely acknowledged, yet there is a shortage of studies that systematically assess learning outcomes from both entertainment and serious games. This gap has led some to question the effectiveness of game-based learning (Shute, Ventura, Bauer, & Zapata-Rivera, 2009). However, despite these concerns, recent advancements in video games, especially in educational contexts, highlight their evolving potential. For instance, Blunt (2009) proved that students using games for learning achieved better test results than traditional instruction methods.

Serious games, particularly simulations, offer a cost-effective and safe way to acquire complex skills and attitudes that are difficult to teach through rote learning (Gee, 2007). These games are also linked to more enduring learning outcomes (Bergeron, 2006). Studies have demonstrated that well-designed learning games can engage players and produce measurable learning outcomes (Prensky, 2006).

In summary, serious games can be a valuable educational tool for boosting motivation (Bellotti, Berta, & De Gloria, 2010).

The Broad Impact of Serious Games on Education and Training

Serious games are increasingly used to enhance education, leveraging their engaging nature to improve learning outcomes. Schools like Quest to Learn in New York use game-based learning models. Educational games such as Skills Arena and Making History have been shown to improve student engagement and performance in subjects like math and history (Shin, Sutherland, Norris, & Soloway, 2012; Watson, Mong, & Harris, 2011).

In higher education, games help students tackle complex topics, such as programming (Muratet, Torguet, Jessel, & Viallet, 2009), while tools allow teachers to create custom educational games without programming knowledge (Sampayo Vargas, Rankin, & Taylor, 2009).

Beyond the classroom, games like Lost in the Middle Kingdom and 3rd World Farmer support independent learning, teaching language skills, and raising awareness about global issues (Shepherd et al., 2011; Hermund et al., 2005). Games like IBM CityOne address modern urban challenges, while Clean World focuses on environmental issues (IBM, 2010; Andre et al., 2014).

Serious games also aid professional training, such as in medicine, where simulations teach surgery procedures (Cowan et al., 2010). Additionally, "data games" like Foldit allow players to contribute to scientific research while learning (Cooper et al., 2010). By integrating educational content into engaging gameplay, these games promote learning across various fields.

Enhancing Financial Literacy Through Serious Games

We have already examined the benefits of serious games and how they enhance the learning process by creating an interactive and engaging environment. This becomes especially meaningful when considering the need for financial literacy, which is vital in helping individuals navigate financial decisions in their everyday lives.

Hoseiny and Niknafas (2020) concluded that serious games enhance the learning process of financial literacy by increasing learning percentages and ensuring that teachings are more stable and durable than conventional methods. They create greater motivation for learners and have a more significant impact when combined with other methods rather than used alone. Additionally, learning through serious games proves to be more effective than traditional educational sessions.

Stock Market Games: Tools for Financial Literacy

In financial literacy, stock market games exemplify the application of serious games, using simulation and competition to teach participants about the complexities of financial markets and investment strategies.

One such example is the Stock Market Game, which was highlighted for its ability to make financial education more engaging and practical. Wood, O'Hare, and Andrews underscore several educational benefits of the game. A key advantage is its motivational component, driven by competition, which challenges students at different grade levels to manage a hypothetical $100,000 portfolio. This element of competition makes the learning process dynamic and encourages students to develop essential skills. Younger students are introduced to basic concepts like stock symbols and trading mechanics, while more advanced learners are encouraged to engage with real-world financial news to make strategic decisions (Wood, O'Hare, & Andrews, 1992).

The Stock Market Game also fosters cooperative learning and decision-making. In teams, students must collaborate on trading strategies, strengthening their ability to think critically and work together effectively. Individual players likewise benefit from decision-making, managing stock selection and trading timing independently. These activities promote the development of practical skills that are essential in understanding capital markets.

Similarly, Tessema (1989) emphasizes the pedagogical value of stock market games in teaching investments. By simulating real-world stock exchanges, the game allows students to engage in hands-on learning through practical activities. Students receive detailed instructions and resources and exposure to professional security analysts. The game has been positively received, with students finding it both stimulating and valuable. It promotes active, student-centered learning, aligning with research that supports this teaching approach as highly effective. According to Tessema, this interactive format makes the Stock Market Game enjoyable and effective for students to grasp investment concepts.

Harter and Harter (2010) demonstrate that playing the Stock Market Game (SMG) alongside teaching lessons from Learning the Market improves student performance on financial concept assessments. Teachers who participated in the study responded positively, with most planning to use the lessons again, even if they do not continue using the SMG. Despite the complexities of isolating the game's effects, the study proves that playing SMG while teaching stock market basics leads to better student outcomes than other methods.

The Role of Lévy Processes in Financial Market Modelling

Lévy processes are stochastic processes characterized by stationary and independent increments. They constitute a broad class of models with sample paths that may be continuous, continuous with occasional discontinuities, or purely discontinuous. Lévy processes are widely used in finance for modeling asset prices, energy finance, and option pricing, as they can capture real-world behaviors such as sudden market movements and complex dynamics (Ibe, 2013).

Levy processes have become a fundamental tool in mathematical finance because they can model real-world market phenomena more effectively than traditional models based

on Brownian motion. Unlike these older models, Levy processes account for the jumps and spikes frequently observed in asset prices, which are critical for understanding market dynamics. This feature allows risk managers and traders to estimate risk better, as they can model more complex price movements, including large, unexpected changes (Cont & Tankov, 2003).

One of the key reasons for using Levy processes is their ability to handle asset return distributions that exhibit "fat tails" and skewness, characteristics that deviate from the normal distribution. These distributions are essential for accurately estimating potential profits and losses and managing the volatility of trading. Traditional models like the Black-Scholes model assume constant volatility, which does not align with market reality. Levy processes, however, offer a more flexible approach by capturing these variations in volatility and improving risk management strategies (Cont & Tankov, 2003; Sato, 1999).

Mathematically, Levy processes are linked to infinitely divisible distributions, a concept that allows complex models to be built from simpler components. The Levy-Khintchine formula is central in connecting these processes to their distributions. Another key result, the Levy-Itô decomposition, allows the construction of processes from distributions, offering a deep understanding of their properties. Levy measures, which provide detailed information about the size and frequency of jumps, play a crucial role in characterizing these processes (Sato, 1999).

In finance, Levy processes are particularly useful for modeling asset prices in both the "real" and "risk-neutral" worlds. This means they can be used to describe how prices behave in the actual market and to model theoretical pricing structures that help traders manage risks in derivative markets. Methods like Monte Carlo simulations and partial integral-differential equations (PIDE) are often used in pricing options and other financial instruments with Levy-driven models (Cont & Tankov, 2003).

Overall, Levy's processes provide a versatile and powerful framework that bridges theoretical models and real-world financial data, offering a more accurate representation of market dynamics.

The Normal Inverse Gaussian Lévy Process in Financial Modelling

The Normal Inverse Gaussian (NIG) distribution is a flexible and analytically tractable probabilistic model widely used in financial and energy market modeling. It is

particularly effective for capturing complex features of time series data, including heavy tails, skewness, and temporal dependence. Its mathematical properties make it a cornerstone in various applications, such as stochastic volatility frameworks, mean-reverting processes, and Lévy-driven dynamics (Barndorff-Nielsen, 1997; Benth & Šaltytė-Benth, 2004).

The NIG distribution's robust structure enables accurate modeling of asset price dynamics, estimation of risk-neutral densities, and derivative pricing. Compared to traditional approaches, the NIG framework is computationally efficient and offers significant advantages in modeling real-world price behaviors and their implications for risk management (Eriksson, Ghysels, & Wang, 2009; Benth & Šaltytė-Benth, 2004). Its versatility has made it a key tool for representing market characteristics like large price fluctuations and mean-reversion phenomena in financial and energy contexts.

Building upon the previous discussions of Lévy processes and their applications in financial modeling, the following section analyzes specifically the normal inverse Gaussian (NIG) Lévy process. This notable variant has gained traction in mathematical finance due to its ability to capture the behavior of financial returns better.

The one- and two-dimensional normal inverse Gaussian (NIG) Lévy process has been analyzed concerning financial data from Germany and Denmark. To evaluate whether the NIG Lévy process is an appropriate model for financial data, uniform residuals were calculated using an algorithm that simulates random variables based on the NIG distribution (Rydberg, 1997).

The NIG Lévy process, first introduced by Barndorff-Nielsen (1995), represents a relatively recent and promising model for financial data. Eberlein and Keller (1995) proposed a similar model, the hyperbolic Lévy process, which was initially applied to the German financial market. Subsequent research showed that the NIG distribution offered a superior fit for log returns on German stocks compared to the hyperbolic distribution, making the NIG Lévy process highly relevant in the field of mathematical finance. Despite its advantages, like other discontinuous Lévy processes with stochastic jumps, the NIG Lévy process faces challenges, particularly due to the existence of multiple equivalent martingale measures (Eberlein & Jacod, 1995).

3. Methodology

This chapter presents the methodological framework employed to design, develop, and evaluate a serious game to enhance financial literacy. The study adopts the Design Science Research (DSR) methodology, a rigorous, iterative approach commonly used to develop innovative artifacts that solve real-world problems. The stock market simulation game developed in this study is a tangible, functional artifact that blends experiential learning principles with gamification techniques (March, & Smith, 1995, Peffers, Tuunanen, Rothenberger, Chatterjee, 2007, Aparicio, et. al 2023, and González-Mendes, Costa, 2025)..

The DSR approach is structured around six core stages: (1) problem identification and motivation, (2) objectives of the solution, (3) design and development of the artifact, (4) demonstration, (5) evaluation, and (6) communication. Each stage is explored throughout this chapter, ensuring the process is systematic and aligned with the overarching research objectives of enhancing financial literacy and promoting informed investment behaviors through an engaging and interactive medium.

3.1 Problem Identification and Motivation

Financial literacy is increasingly recognized as a critical life skill essential for effective participation in modern financial systems. Studies have shown that low levels of financial literacy are linked to suboptimal financial behaviors, such as insufficient saving, over-indebtedness, and poor investment choices (Lusardi & Mitchell, 2011). Despite its importance, financial literacy remains alarmingly low in many populations, with disparities particularly pronounced among young adults, low-income groups, and individuals with limited access to formal education (Capuano & Ramsay, 2011).

Traditional methods of teaching financial literacy often rely on static, lecture-based approaches that fail to engage learners or provide opportunities for practical application (Hoseiny & Niknafas, 2020). Furthermore, the abstract nature of financial concepts, such as risk management and portfolio diversification, poses additional challenges for learners with no prior exposure to finance (Lusardi, Mitchell, & Curto, 2010; Rodrigues et al., 2020).

While educational initiatives have sought to address these challenges, many fail to achieve their intended impact due to Low Engagement, Lack of Interactivity, and Limited Practical Application**.**

Traditional methods, such as text-heavy materials and theoretical lessons, struggle to attract learners (Hoseiny & Niknafas, 2020). Few programs incorporate experiential learning opportunities essential for deeper understanding and retention (Harter & Harter, 2010).

Learners often struggle to connect abstract financial concepts to real-world scenarios (Tessema, 1989).

This research identifies these gaps as key barriers to financial literacy and positions serious games as a promising solution. By simulating stock market dynamics in an interactive and controlled environment, serious games offer a unique opportunity to make financial education engaging, practical, and accessible.

3.2 Objectives of the Solution

The primary goal of this study is to develop a serious game that enhances financial literacy by fostering an intuitive understanding of key financial concepts and encouraging informed decision-making in investment contexts. To achieve this, the game is designed with the following objectives:

- Simplify Complex Financial Concepts,
- Promote Experiential Learning,
- Encourage Strategic Thinking,
- Foster Long-Term Financial Engagement,
- Evaluate Financial Decision-Making Skills.

Financial concepts such as volatility, diversification, and risk-reward trade-offs are presented in an intuitive, accessible manner. Players learn by doing, experimenting with investment strategies, and reflecting on outcomes in a risk-free environment. The game challenges players to analyze ambiguous scenarios, weigh potential risks, and adapt their strategies dynamically. The game aims to inspire continued interest in financial education beyond the gameplay experience by making learning enjoyable and relevant. The game

serves not only as an educational tool but also to assess 'players' decision-making processes under uncertainty.

3.3 Design and Development of the Artifact

The game is built on the principles of experiential learning theory (Kolb, 1984) and constructivist learning theory, emphasizing active participation, reflection, and knowledge construction through hands-on experiences. According to the framework of March and Smith (1995), the game serves as an instantiation—a functional artifact that operationalizes theoretical principles through gamification elements, such as dynamic feedback, ambiguous scenarios, and performance metrics. By integrating these features, the game engages players and serves as a tool for testing and refining educational strategies for improving financial literacy.

The artifact consists of three primary components: Dynamic Market Simulation, Ambiguous Events, and User Feedback Mechanisms.

The game simulates the behavior of two fictional stocks, whose prices fluctuate based on stochastic processes and event-driven adjustments. Players encounter random events that influence stock prices in unpredictable ways, reflecting real-world market uncertainties. Players receive end-game feedback reflecting their portfolio value, encouraging reflection on investment decisions.

The game is developed as a web-based application to ensure broad accessibility. According to good practices, referred by several authors (e.g., Costa, & Aparício 2006; Costa & Costa, 2013), the technical stack includes:

- The front end is developed in HTML, CSS, and JavaScript to provide an intuitive, user-friendly interface.
- The backend includes the Logic for stock price calculations, event handling, and performance tracking.
- The Normal Inverse Gaussian (NIG) process is employed to model stock price fluctuations, capturing heavy tails and skewness characteristic of financial time series.

The development process follows an iterative approach, incorporating potential user feedback to refine gameplay mechanics and educational content.

3.4 Demonstration

The artifact is demonstrated through a series of pilot sessions with participants from diverse backgrounds, including university students, young professionals, and individuals with limited financial literacy. The demonstration process involves introduction and instructions, gameplay sessions, and performance feedback.

Participants are provided with a brief tutorial on game mechanics, objectives, and basic financial concepts. Players engage with the game over multiple iterations of time, making investment decisions and responding to market events. At the end of each session, participants receive a message summarizing their performance.

3.5 Evaluation

The evaluation phase is designed to gather informal, qualitative feedback from participants interacting with the stock market simulation game. This approach prioritizes understanding their spontaneous impressions and perceptions of the game, focusing on its usability, engagement, and educational potential.

After engaging with the game, participants provide their opinions through an open-ended, unstructured format. The feedback is gathered in conversational settings, where participants are encouraged to share their thoughts freely without the constraints of surveys or formal assessments. This process allows for genuine and natural responses about their experience.

Key areas of interest include:

- First impressions evaluate how participants initially perceive the game's concept, interface, and mechanics.
- Overall experience consists of the general opinions on how engaging or enjoyable the gameplay was.

- Perceived educational value involves analyzing whether participants learned something new about stock market concepts or investment strategies.
- Constructive criticism is spontaneous suggestions or observations about what could be improved in the game.

The opinions collected are reviewed and categorized to identify common themes, strengths, and areas for improvement. This informal analysis involves highlighting positive aspects, identifying challenges, and gathering improvement Ideas.

Notes are taken concerning which elements of the game participants found most appealing, such as the gameplay mechanics, visual design, or event system. Understanding where participants encountered difficulties or confusion, such as unclear instructions or overly complex gameplay. Those notes of specific suggestions participants may offer, such as features, are relevant to add and contribute to game adjustment.

Although participants are not explicitly asked to evaluate the educational objectives, their spontaneous feedback often reveals insights into the 'game's ability to convey financial concepts. Observations such as comments on the realism of the events or reflections on their decision-making process can provide valuable indicators of the 'game's impact.

The collected feedback forms the basis for iterative improvements to the game. Even in an informal setting, participant opinions can highlight significant areas for enhancement. This process ensures that the game evolves in response to real user experiences, becoming more effective in achieving its goals.

GitHub link: https://github.com/AfonsoCapelo1/Proposing-a-market-simulation-game

4. RESULTS AND DISCUSSION

This chapter presents the final evaluation of the stock market simulation game designed to enhance financial literacy. The evaluation focused on assessing the game's effectiveness in achieving its educational objectives and its impact on participants' understanding of key financial concepts. The findings are drawn from comprehensive user feedback, gameplay observations, and performance analysis, providing a thorough understanding of how the game influenced participants' decision-making, financial knowledge, and engagement.

The 'game's design, which incorporates ambiguous market events, strategic decision-making, and real-world financial scenarios, was evaluated across diverse user groups with varying levels of financial literacy. The evaluation aimed to explore how well the game facilitated the development of critical skills, including risk management, portfolio diversification, and strategic thinking under uncertainty. Through the analysis of participant experiences, this chapter highlights the educational impact of the game and outlines the insights gathered for future refinements.

Key areas covered in this chapter include an overview of the participants, gameplay observations, informal feedback, and an evaluation of the educational outcomes. This section concludes by discussing the key insights gained from the evaluation and the refinements needed to enhance the 'game's educational effectiveness further.

4.1 Problem Identification

Financial literacy is essential for individuals to make informed and effective financial decisions. With the growing complexity of financial markets and investment opportunities, there is a pressing need to improve individuals' understanding of financial concepts such as risk, return, portfolio diversification, and market volatility (Lusardi & Mitchell, 2011). However, traditional finance teaching methods often fail to engage learners, particularly those without formal financial education, making it difficult for them to build confidence in their financial decision-making (Gallery et al., 2011).

Current financial education tools, such as textbooks, lectures, and static simulations, often fail to provide an interactive and dynamic learning environment. These tools are

typically perceived as dry, theoretical, and disconnected from the real-world scenarios that individuals face when making financial decisions (Capuano & Ramsay, 2011). As a result, individuals, particularly young professionals, university students, and people without formal financial education, struggle to acquire the skills necessary to make sound financial decisions. This lack of financial literacy can lead to poor investment decisions, inadequate financial planning, and long-term financial instability (Hung et al., 2012).

To address this issue, a more engaging and effective solution is needed. The stock market simulation game is designed to immerse users in real-world financial decision-making, enabling them to experience first-hand the challenges of navigating a fluctuating market while learning core financial concepts. The game's interactive design aims to bridge the gap between theoretical knowledge and practical application by offering a hands-on, engaging learning experience (Harter & Harter, 2010).

4.2 Objectives of the Solution

The primary objective of the stock market simulation game was to enhance financial literacy by immersing players in a dynamic, interactive environment that mirrors real-world investment scenarios. Based on the objectives defined in Chapter 1, the following results were observed:

The game successfully introduced fundamental financial concepts, such as risk, reward, and diversification, by simulating fluctuating stock prices influenced by stochastic processes and ambiguous events. Players were required to think critically and make strategic decisions in response to the uncertainty created by these market fluctuations. As a result, players demonstrated improved decision-making skills and a deeper understanding of how market volatility affects investment outcomes. Furthermore, participants reported increased confidence in their ability to make informed financial decisions following the gameplay experience.

The game is designed to introduce players to fundamental financial concepts engagingly and interactively. It starts by teaching the basics of investing, such as understanding the principle of "buy low, sell high" and the balance between risk and return. Players experience market volatility dynamics as stock prices fluctuate in response to simulated events, helping them grasp how real-world factors influence investment

outcomes. Through gameplay, they are encouraged to diversify their investments, learning how spreading risk across various assets can protect against potential losses.

Decision-making under uncertainty is a key focus, with ambiguous scenarios requiring players to think critically and adapt their strategies. This process not only reinforces financial principles but also cultivates strategic planning skills. Players are challenged to look beyond short-term gains and align their actions with long-term financial goals, emphasizing the importance of thoughtful planning in achieving sustainable success.

The game also mirrors the emotional challenges of investing, such as resisting impulsive decisions or managing reactions to sudden market changes. By navigating these situations, players develop patience, discipline, and better risk management skills. The safe, risk-free environment encourages experimentation, allowing players to make mistakes and learn from them without real-world consequences.

Ultimately, the game aims to build confidence in financial decision-making. Players gain a solid foundation in assessing opportunities, managing risks, and making calculated decisions, empowering them to apply these skills to their personal finances. Beyond immediate learning, the game sparks curiosity about financial topics and inspires players to pursue further retirement planning, savings, and investment education.

Moreover, the skills developed through the game extend beyond financial literacy. Players enhance their critical thinking, self-discipline, and strategic decision-making abilities—valuable qualities in many other areas of life. By blending financial learning with broader life skills, the game provides an enriching and practical experience that leaves players better prepared for real-world challenges.

4.3. Design and Development

In this step, we focus on the creation of the artifact, specifically the stock market simulation game and the underlying NIG (Normal Inverse Gaussian) process that models stock price movements. The game aims to simulate realistic financial market dynamics by integrating stochastic processes and random events.

4.3.1. Stock Price Modeling and the Role of Random Events

The stock market simulation game uses a combination of stochastic processes and random events to model stock price movements. The core of the price update mechanism relies on the Normal Inverse Gaussian (NIG) process, a powerful tool for simulating financial market dynamics. The NIG process captures both continuous price changes (via Brownian motion) and discrete jumps (via the Lévy component), offering a realistic approach to modeling stock prices.

4.3.2. The Role of Events

The game incorporates random events, detailed in Figure 1, that influence stock prices, designed to simulate the unpredictable nature of real-world market dynamics. These events are randomly triggered at each iteration of the game, with specific probabilities assigned to reflect their likelihood. Each event impacts stock prices differently, simulating market shocks, trends, or external factors. For instance, some events may represent positive economic news or corporate successes, causing stock prices to rise, while others might mimic adverse situations such as economic downturns or company scandals, leading to price declines.

To ensure educational value and realism, the events are intentionally designed to include ambiguous descriptions, encouraging players to analyze the market's behavior rather than rely solely on the event's narrative. This approach helps players understand the complex and sometimes counterintuitive nature of market reactions to news and external stimuli.

Table I - Random events that influence stock prices

Event	Description	Effect	Probability of occurrence
Product Breakthrough	Tech Innovations Inc. develops a revolutionary product.	5% increase in Stock A price.	9.44%
New Product Line	Tech Innovations Inc. launches a popular new product line.	10% increase in Stock A price.	4.72%
Increased Competition	New competitors enter the tech market.	5% decrease in Stock A price.	9.44%
Tech Patent Dispute	Tech Innovations Inc. faces a legal battle over patent rights.	10% decrease in Stock A price.	4.72%
New International Renewable Energy Deal	Green Energy Corp. signs a lucrative international deal.	5% increase in Stock B price.	9.44%
Government Subsidy for Renewable Energy	The government provides subsidies to renewable energy firms.	10% increase in Stock B price.	4.72%
Environmental Regulations Tightened	Stricter regulations increase operational costs for Green Energy Corp.	5% decrease in Stock B price.	9.44%
Energy Price Collapse	Renewable energy prices drop.	10% decrease in Stock B price	4.72%
Economic Recovery	The economy shows signs of recovery.	5% increase in both Stock A and Stock B prices.	9.44%
Global Technology and Sustainability Partnership	Tech Innovations Inc. and Green Energy Corp. announced a collaboration.	10% increase in both Stock A and Stock B prices.	4.72%
Supply Chain Collapse	A supply chain crisis affects production costs and timelines.	5% decrease in both Stock A and Stock B prices.	9.44%
Global Recession	Warnings of a global recession.	10% decrease in both Stock A and Stock B prices.	4.72%
Neutral Economic Data Release	New economic data shows no significant changes.	No change (0%) in stock price for both Stock A and Stock B	15%

These events are incorporated in the price update at each time step, with the price change from the NIG process augmented by the effects of the triggered event.

4.3.3. The NIG Process for Stock Price Updates

The **Normal Inverse Gaussian (NIG)** process serves as the underlying model for stock price changes in the game. It is a type of **Lévy process** that incorporates both continuous and jump components. The stock price at each iteration is updated using the NIG process, which is characterized by the following parameters:

- α **(Alpha)**: Controls the scale of fluctuations.
- β **(Beta)**: Determines the direction of price jumps (positive for upward, negative for downward).
- δ **(Delta)**: Governs the "tail behavior," which dictates how extreme values behave.
- μ **(Mu)**: Represents the central tendency or drift, determining the general direction of price movement.

The NIG process ensures that stock price changes are **independent** and **stationary**, meaning the statistical properties of the price changes do not vary over time. The update for stock price change, considering the NIG process, is given by:

$$\Delta P_{NIG} = \mu + \frac{\delta\beta}{\sqrt{\alpha^2 - \beta^2}} . Z_t$$

Where **Z_t** is a random variable drawn from a standard normal distribution to introduce randomness into the price change, this formulation allows the stock price to experience both **continuous diffusion** and **discrete jumps**, mimicking real-world financial market behavior.

4.3.4. Combining Events and NIG Process

At each time step, the stock price is updated by combining the effects of the **NIG process** and the **random events**. The general update formula is as follows:

$$P(t+1) = P(t) \times \exp\left(\Delta P_{NIG} + \Delta P_{event}\right)$$

Where:

- **P(t)** is the stock price at time **t**.
- **ΔP_NIG** is the price change from the NIG process.
- **ΔP_event** is the price change due to the triggered event.

This ensures that the stock price fluctuates in response to both the continuous price movement driven by the NIG process and any discrete jumps caused by the random events.

4.3.5. Examples of Price Updates

To illustrate how the price updates work, here are a few examples of how different scenarios affect the stock price:

- **Example 1: No Event (Normal Day)**
  - The stock price at time t: 100
  - NIG process generates a +1.5% price change.
  - The new stock price will be: $P(t+1) = 100 \times \exp(1.5\%) = 100 \times 1.015 = 101.5$
- **Example 2: Positive News Event**
  - The stock price at time t: 100
  - NIG process generates a -1% price change.
  - A positive news event causes a +5% price change.
  - The new stock price will be: $P(t+1) = 100 \times \exp((-1)\% + 5\%) = 100 \times 1.04 = 104$
- **Example 3: Economic Shock**
  - The stock price at time t: 100
  - NIG process generates a +2% price change.
  - An economic shock occurs, causing a -10% price change.
  - The new stock price will be: $P(t+1) = 100 \times \exp(2\% + (-10)\%) = 100 \times 1.08 = 108$:

The combination of the NIG process and random events provides a robust and realistic model for simulating stock price movements in the game. The NIG process ensures that the stock prices exhibit both continuous fluctuations and discrete jumps while the random events add a layer of uncertainty and market dynamics. This design closely mirrors the behavior of financial markets, allowing players to experience a dynamic, unpredictable environment that fosters learning about investment strategies and financial markets.

4.4 Demonstration

The demonstration of the stock market simulation game illustrates how the artifact operates and how it achieves its educational objectives. The demonstration introduces users to the game interface, mechanics, and key features to enhance financial literacy and strategic decision-making.

4.4.1 Initial Setup

When players begin the game, they are greeted with a user-friendly interface that outlines the starting conditions. Each player starts with a cash balance of $1000, and two stocks — Stock A and Stock B — are initially available for trading, both priced at $100. The first market event is displayed immediately, offering ambiguous clues about potential market changes.

Players are provided with clear controls: the **Buy** option allows them to purchase shares of either stock, while **Sell** enables them to sell shares they own. The **Next Time Iteration** button progresses the game to the next period, updating stock prices and events. If players wish to end the session, they can click **End Game**, which summarizes their financial performance.

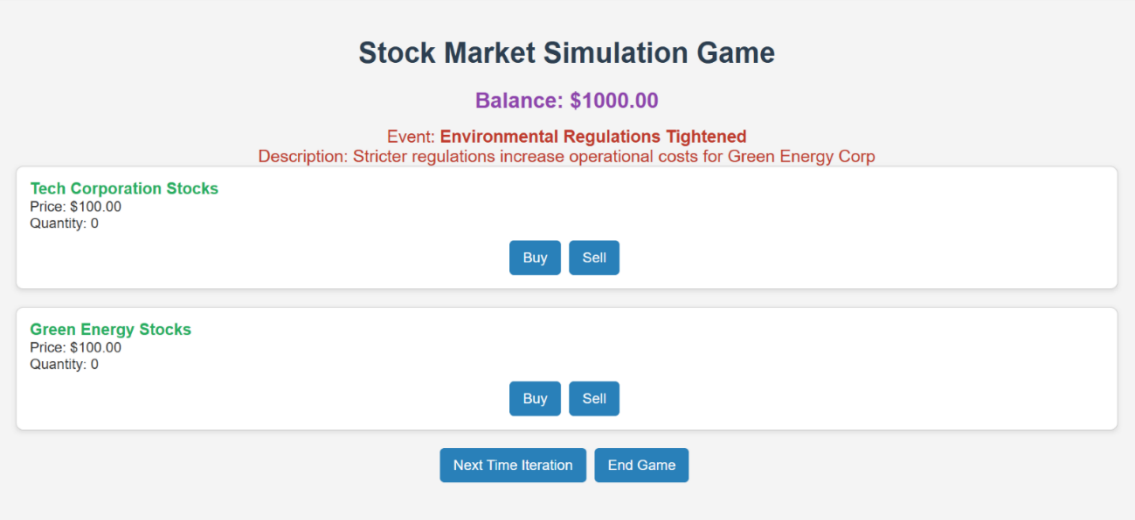

Figure 1-Layout of the Game

4.4.2 Understanding the Stocks

The game features two stocks, each designed to represent specific market sectors: Stock A (Tech Corporation Stocks) and Stock B (Green Energy Stocks). Stock A reflects high-growth industries driven by technological advancements and market trends, offering significant potential for gains but also carrying high volatility. Stock B mirrors the global shift toward sustainability, influenced by environmental policies and innovations. This stock balances growth potential with a degree of market uncertainty.

4.4.3 Advancing Through the Game

Each iteration in the game brings new market conditions for players to navigate. Stock prices are adjusted based on random market factors, encouraging players to analyze trends and adapt their strategies. Additionally, ambiguous descriptions of market events are provided, challenging players to interpret their potential impacts on stock prices.

4.4.4 Trading Stocks

Players make decisions based on their analysis of the market. They can select a stock and click the 'Buy' button as many times as they want to purchase shares, with each click adding more shares to their portfolio. The cost of each purchase is deducted from their balance. Similarly, players can sell shares they own anytime to realize gains or adjust their portfolio. The proceeds from the sale are added to their balance. This dynamic system allows players to buy and sell shares multiple times during a single iteration, allowing them to adjust their strategies based on the evolving market conditions.

4.4.5 Ending the Game

Players can conclude the game anytime by clicking "End Game." When they do, a pop-up will display their score based on their current balance plus the market value of the stocks in their portfolio. Players are also encouraged to reflect on their decisions and strategies throughout the game as part of the performance analysis.

The demonstration of these mechanics highlights the 'game's interactive design, emphasizing player decision-making and the direct relationship between their strategies and financial outcomes.

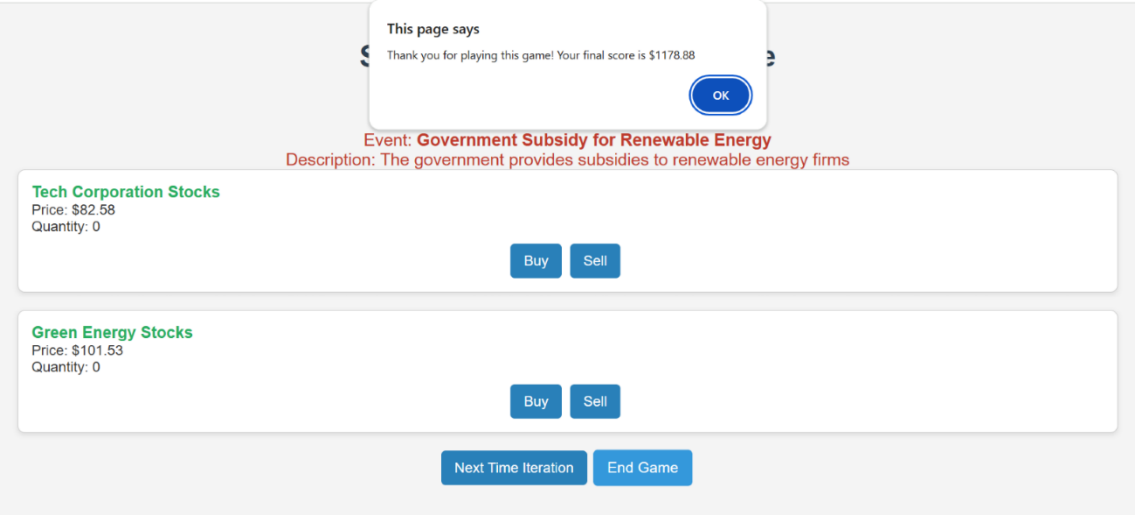

Figure 2-End of the Game

4.5. Evaluation Step

The stock market simulation game was evaluated by analyzing its educational effectiveness and user experience. This step focused on analyzing participant demographics, gameplay observations, informal feedback, and the educational impact to draw evidence-based conclusions about the 'game's success in fostering financial literacy.

4.5.1 Participant Overview

The evaluation engaged a diverse cohort of 12 participants, encompassing individuals from various educational and professional backgrounds, to ensure a representative analysis of the 'game's applicability. **25%** (3) university students from non-finance disciplines, providing insight into how the game resonates with individuals with limited exposure to finance. **50%** (6) of the young professionals have some practical financial decision-making experience but minimal formal training in investing. **25% (3)** individuals with no prior financial education, offering a perspective on how the game performs as a foundational learning tool.

This participant diversity facilitated a comprehensive evaluation of the 'game's ability to bridge gaps in financial literacy across multiple demographic segments.

4.5.2 Gameplay Observations

The gameplay sessions revealed important trends in participant engagement, decision-making strategies, and interactions with the game mechanics.

Over 66% of participants completed at least seven rounds, underscoring the game's ability to maintain attention and interest. The unpredictable market scenarios and dynamic events contributed to high engagement, with participants frequently citing the 'game's ability to simulate real-world unpredictability as a key motivator.

Novice players demonstrated measurable improvement in their decision-making, progressively adopting strategies such as portfolio diversification and risk mitigation as their understanding deepened through gameplay. Experienced players utilized the game as a testing ground for complex strategies, such as scenario forecasting and tactical risk-taking.

Participants enjoyed the post-game analysis, which encouraged reflection on investment decisions. While most participants adapted to the ambiguity of event descriptions, some novice players found them overly abstract, occasionally leading to confusion about their relevance to gameplay.

4.5.3 Informal Feedback Analysis

Feedback from participants was instrumental in identifying strengths and areas for potential refinement in the game design.

In terms of positive aspects, participants highlighted the game's immersive and authentic market dynamics. One player noted, “It felt like every decision mattered, just like in a real investment scenario". Participants frequently mentioned improved comprehension of financial concepts, including diversification and risk management. Including unpredictable events was cited as challenging and rewarding, fostering a realistic learning environment.

In what concerns challenges**, s**ome participants, particularly those without a financial background, found certain event descriptions ambiguous, making it difficult to anticipate

their implications. A few users suggested that additional onboarding guidance could better support those with limited prior knowledge of finance or gaming.

Participants also suggested improvements, such as enhancing visual aids and event descriptions to provide clearer contextual hints without diminishing the complexity of decision-making. Another suggestion was to incorporate a warning mechanism to help players recognize potential errors in judgment, thereby reinforcing the educational aspects of the gameplay.

4.5.4 Educational Impact

The game successfully achieved its educational objectives, as evidenced by self-reported learning outcomes and observed behavioral changes: Improved Financial Understanding, Promotion of Financial Literacy, and Enhanced Critical Thinking.

It is possible to say that it improved financial understanding because post-game discussions revealed frequent use of key financial terms, reflecting strong retention and application of concepts introduced during gameplay.

Some participants (50%) expressed interest in further learning, showcasing the game's potential to inspire ongoing financial education. This may lead us to conclude that it contributes to promoting financial literacy.

Participants acknowledged the 'game's role in improving their ability to analyze ambiguous scenarios and strategize effectively under uncertainty. One participant remarked, "The game challenged me to anticipate and adapt to market changes, which felt highly realistic". This may lead to the statement that it contributes to enhancing critical thinking.

4.5.5 Key Insights and Final Refinements

While feedback affirmed the 'game's educational value, several refinements were proposed to enhance user experience and accessibility.

A more interactive and guided tutorial could support new players in understanding the mechanics and objectives, particularly those with limited financial

knowledge. Additional context for ambiguous events could improve accessibility without reducing the challenge level. Expanding the feedback system to include in-depth analysis of player decisions and their market consequences could enhance the learning experience.

5. CONCLUSIONS

The stock market simulation game demonstrated significant potential as an educational tool for improving financial literacy. By immersing participants in an interactive, dynamic learning environment, the game achieved its primary objective: to foster a deeper understanding of financial concepts, such as risk management, portfolio diversification, and strategic decision-making under uncertainty.

The key findings of this study are as follows: Enhanced financial knowledge, engagement through Ambition, broad applicability, and motivation for lifelong learning. Participants reported improved comprehension of fundamental financial concepts self-assessments and observed gameplay behaviors indicating greater confidence in decision-making. Including ambiguous market events effectively simulated real-world financial uncertainty, encouraging critical thinking and adaptability. The game successfully engaged participants from diverse demographic and educational backgrounds, highlighting its potential to bridge financial literacy gaps across varied audiences. A significant proportion of participants expressed interest in further financial education after playing, indicating the 'game's ability to inspire continued learning.

This study contributes to the field of financial literacy education in several ways: Innovative Pedagogy, Educational Game Design, and Empirical Insights:

The game introduces a novel approach to financial education by combining the Normal Inverse Gaussian (NIG) process with random events to simulate realistic stock price dynamics. Integrating gamification principles—such as player feedback and ambiguous scenarios—provides a blueprint for designing engaging and impactful educational games. Evaluating user experiences offers valuable insights into how serious games can influence financial knowledge and behavior, filling a gap in the literature on the practical application of such tools.

Implications are at tree levels: education, policymakers, and developers. For Educators, the game is a scalable, adaptable resource for teaching financial literacy in academic and non-academic settings. For Policymakers, the findings underscore the importance of interactive learning tools in addressing financial illiteracy, particularly among young professionals and underserved populations. For Developers, the success of

this simulation highlights the demand for realistic, user-centric financial education tools that blend theory and practice.

5.2 Limitations and Future Work

While the study yielded promising results, several limitations were identified. The study primarily assessed immediate learning outcomes, with limited data on long-term retention or behavioral changes. While the game simulates realistic financial dynamics, it necessarily simplifies certain complexities of actual markets to maintain accessibility. The evaluation involved a relatively small cohort of 12 participants, limiting the generalizability of findings to broader populations.

Building on the current study, future research and development efforts could address these limitations and expand the game's scope by scaling participant engagement through large-scale studies with diverse populations to validate findings and explore demographic-specific impacts, tracking participants over extended periods to assess the game's influence on financial behaviors and decision-making, and developing more robust tutorials and adaptive difficulty levels to support players with varying financial knowledge and gaming skills. Additional advancements could include incorporating financial instruments, such as bonds or derivatives, to create a more comprehensive simulation of market dynamics, expanding the game to mobile platforms or virtual reality environments to increase accessibility and engagement, and collaborating with educational institutions to integrate the game into formal finance and economics courses, paired with complementary instructional materials.

In conclusion, the stock market simulation game marks a significant step forward in leveraging serious games to enhance financial literacy. An engaging, practical approach to learning financial concepts bridges the gap between theory and application. While limitations remain, the game's success underscores its potential as a transformative educational tool, paving the way for future innovations in financial education.

REFERENCES

Adams, G. A., & Rau, B. L. (2011). Putting off tomorrow to do what you want today: planning for retirement. American Psychologist, 66(3), 180. https://doi.org/10.1037/a0022131

Aparicio, M., & Costa, C. J. (1999). Utilização do jogo de simulação de gestão SIM 7 como instrumento pedagógico: um estudo exploratório. Utilização do jogo de simulação de gestão SIM 7 como instrumento pedagógico: um estudo exploratório, (7), 75-85.

Aparicio, J.T., Aparicio, M., Costa, C.J. (2023). Design Science in Information Systems and Computing. In: Anwar, S., Ullah, A., Rocha, Á., Sousa, M.J. (eds) Proceedings of International Conference on Information Technology and Applications. Lecture Notes in Networks and Systems, vol 614. Springer, Singapore. https://doi.org/10.1007/978-981-19-9331-2_35

Barbosa, A. F., Pereira, P. N., Dias, J. A., & Silva, F. G. (2014). A new methodology of design and development of serious games. International Journal of Computer Games Technology, 2014(1), 817167. https://doi.org/10.1155/2014/817167

Barndorff-Nielsen, O. E. (1994). Normal \\ inverse Gaussian processes and the modelling of stock returns. Department of Mathematical Sciences, Aarhus University.

Barndorff-Nielsen, O. E. (1997). Processes of normal inverse Gaussian type. *Finance and Stochastics*, 2(1), 41–68.

Behrman, J. R., Mitchell, O. S., Soo, C. K., & Bravo, D. (2012). How financial literacy affects household wealth accumulation. American Economic Review, 102(3), 300-304. https://doi.org/10.1257/aer.102.3.300

Bellotti, F., Berta, R., & De Gloria, A. (2010). Designing effective serious games: opportunities and challenges for research. International Journal of Emerging Technologies in Learning (iJET), 5(2010). https://doi.org/10.3991/ijet.v5s3.1500

Benth, F. E., & Šaltytė-Benth, J. (2004). The normal inverse Gaussian distribution and spot price modelling in energy markets. *International Journal of Theoretical and Applied Finance*, 7(2), 177–192.

Bergeron, B. P. (2006). Developing serious games. Hingham (Mass.): Charles River Media.

Bernheim, B. D., & Garrett, D. M. (2003). The effects of financial education in the workplace: Evidence from a survey of households. Journal of public Economics, 87(7-8), 1487-1519. https://doi.org/10.1016/s0047-2727(01)00184-0

Blunt, R. (2009). Do serious games work? Results from three studies. ELearn, 2009(12). https://doi.org/10.1145/1661377.1661378

Capuano, A., & Ramsay, I. (2011). What causes suboptimal financial behaviour? An exploration of financial literacy, social influences and behavioural economics. An Exploration of Financial Literacy, Social Influences and Behavioural Economics (March 23, 2011). U of Melbourne Legal Studies Research Paper, (540). https://doi.org/10.2139/ssrn.1793502

Christelis, D., Jappelli, T., & Padula, M. (2010). Cognitive abilities and portfolio choice. European Economic Review, 54(1), 18-38. https://doi.org/10.1016/j.euroecorev.2009.04.001

Cole, S., & Fernando, N. (2008). Assessing the importance of financial literacy. ADB Finance for the Poor, 9(2), 1-6.

Cooper, S., Treuille, A., Barbero, J., Leaver-Fay, A., Tuite, K., Khatib, F., ... & Popović, Z. (2010, June). The challenge of designing scientific discovery games. In Proceedings of the Fifth international Conference on the Foundations of Digital Games (pp. 40-47). https://doi.org/10.1145/1822348.1822354

Corti, K. (2006). Games-based learning; a serious business application. PIXE Learning Limited.

Costa, C. & Costa, P. (2013). Developing a game in the context of an open source community. In Proceedings of the 2013 International Conference on Information Systems and Design of Communication (ISDOC '13). Association for Computing

Machinery, New York, NY, USA, 108–112. https://doi.org/10.1145/2503859.2503876

Costa, C. & Costa, P. (2011). A peace war game application. In Proceedings of the 2011 Workshop on Open Source and Design of Communication (OSDOC '11). Association for Computing Machinery, New York, NY, USA, 71–74. https://doi.org/10.1145/2016716.2016735

Costa, C., & Aparício, M. (2006). Computer Game–Discussing Development Process. In Proceedings of IRIS (Vol. 29).

Costa, C. J. (2025). Integrating LLMs in Gamified Systems. *arXiv preprint arXiv:2503.11458*.

Costa, J. & Costa, C. (2010) Market game. In Proceedings of the Workshop on Open Source and Design of Communication (OSDOC '10). Association for Computing Machinery, New York, NY, USA, 59–60. https://doi.org/10.1145/1936755.1936774

Cowan, B., Sabri, H., Kapralos, B., Porte, M., Backstein, D., Cristancho, S., & Dubrowski, A. (2010). A serious game for total knee arthroplasty procedure, education and training. Journal of CyberTherapy & Rehabilitation (JCR), 3(3). https://doi.org/10.1016/j.sbspro.2010.03.539

Eberlein, E., & Jacod, J. (1997). On the range of options prices. Finance and Stochastics, 1(2), 131–140. https://doi.org/10.1007/s007800050019

Eberlein, E., & Keller, U. (1995). Hyperbolic distributions in finance. Bernoulli. https://doi.org/10.2307/3318481

Eriksson, A., Ghysels, E., & Wang, F. (2009). The normal inverse Gaussian distribution and the pricing of derivatives. *Journal of Derivatives*, 16(3), 23.

Fratantoni, M. C. (1998). Homeownership and investment in risky assets. Journal of Urban Economics, 44(1), 27-42. https://doi.org/10.1006/juec.1997.2058

Frederik, D. G., Peter, M., & Jan, V. L. (2010, September). Uncharted waters? Exploring experts' opinions on the opportunities and limitations of serious games for foreign language learning. In Proceedings of the 3rd International Conference on Fun and Games (pp. 107-115). https://doi.org/10.1145/1823818.1823830

Gallery, G., & Gallery, N. (2010). Rethinking financial literacy in the aftermath of the global financial crisis. Griffith Law Review, 19(1), 30-50. https://doi.org/10.1080/10854667.2010.10854667

Gallery, N., Gallery, G., Brown, K., Furneaux, C., & Palm, C. (2011). Financial literacy and pension investment decisions. Financial Accountability & Management, 27(3), 286-307. https://doi.org/10.1111/j.1468-0408.2011.00526.x

Garman, E. T. (1997). Personal finance education for employees: Evidence on the bottom-line benefits. Journal of Financial Counseling and Planning, 8(2), 1.

González-Mendes, S., Costa, C.J. (2025). Design Science Approach for a New Business Model Canvas with Blockchain. In: Prieto, J., Vargas, R.P., Lage, O., Machado, J.M., Bálint, M. (eds) Blockchain and Applications, 6th International Congress. BLOCKCHAIN 2024. Lecture Notes in Networks and Systems, vol 1256. Springer, Cham. https://doi.org/10.1007/978-3-031-81928-5_13

Gee, J. P. (2003). What video games have to teach us about learning and literacy. Computers in entertainment (CIE), 1(1), 20-20. https://doi.org/10.1145/950566.950595

Greitzer, F. L., Kuchar, O. A., & Huston, K. (2007). Cognitive science implications for enhancing training effectiveness in a serious gaming context. Journal on Educational Resources in Computing (JERIC), 7(3), 2-es. https://doi.org/10.1145/1281320.1281322

Guiso, L., & Jappelli, T. (2005). Awareness and stock market participation. Review of Finance, 9(4), 537-567. https://doi.org/10.1007/s10679-005-5000-8

Harter, C., & Harter, J. F. (2010). Is financial literacy improved by participating in a stock market game?. Journal for economic educators, 10(1), 21-32.

Hoseiny, S., & Niknafs, A. (2020, December). Study of the Serious Games Capacity in Promoting Financial Literacy. In 2020 International Serious Games Symposium (ISGS) (pp. 81-87). IEEE. https://doi.org/10.1109/isgs51981.2020.9375426

Hung, A., Yoong, J., & Brown, E. (2012). Empowering women through financial awareness and education. OECD Working Papers on Finance, Insurance and Private Pensions, No. 14, OECD Publishing. https://doi.org/10.1787/5k9d5v6kh56g-en

Ibe, O. (2013). Markov processes for stochastic modeling. Newnes.

Jonubi, A., & Abad, S. (2013). The impact of financial literacy on individual saving: An exploratory study in the Malaysian context. Transformations in Business & economics, 12(1), 28.

Ken-Iti, S. (1999). Lévy processes and infinitely divisible distributions (Vol. 68). Cambridge university press.

Khan, M. S. R., Rabbani, N., & Kadoya, Y. (2020). Is financial literacy associated with investment in financial markets in the United States?. Sustainability, 12(18), 7370. https://doi.org/10.3390/su12187370

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Kumari, D. A. T. (2017). Financial literacy: An essential tool for empowerment of women through financial inclusion – literature review" Equality and Management. Poland: Faculty of Economics and Management, University of Szczecin.

Kumari, D. A. T. (2020). The Impact of Financial Literacy on Investment Decisions: With Special Reference to Undergraduates in Western Province, Sri Lanka. Asian Journal of Contemporary Education, 4(2), 110-126. https://doi.org/10.18488/journal.137.2020.42.110.126

Laamarti, F., Eid, M., & El Saddik, A. (2014). An overview of serious games. International Journal of Computer Games Technology, 2014(1), 358152. https://doi.org/10.1155/2014/358152

Lusardi, A. (2019). Financial literacy and the need for financial education: Evidence and implications. Swiss Journal of Economics and Statistics, 155(1), 1-8. https://doi.org/10.1186/s41937-019-0027-5

Lusardi, A., & Mitchell, O. S. (2007). Baby boomer retirement security: The roles of planning, financial literacy, and housing wealth. Journal of monetary Economics, 54(1), 205-224. https://doi.org/10.1016/j.jmoneco.2006.12.001

Lusardi, A., & Mitchell, O. S. (2008). Planning and financial literacy: How do women fare?. American economic review, 98(2), 413-417. https://doi.org/10.1257/aer.98.2.413

Lusardi, A., & Mitchell, O. S. (2011). Financial literacy and planning: Implications for retirement wellbeing (No. w17078). National Bureau of Economic Research. https://doi.org/10.3386/w17078

Lusardi, A., & Mitchelli, O. S. (2007). Financial literacy and retirement preparedness: Evidence and implications for financial education: The problems are serious, and remedies are not simple. Business economics, 42, 35-44. https://doi.org/10.2145/20070104

Lusardi, A., Mitchell, O. S., & Curto, V. (2010). Financial literacy among the young. Journal of consumer affairs, 44(2), 358-380. https://doi.org/10.1111/j.1745-6606.2010.01173.x

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. Decision support systems, 15(4), 251-266. https://doi.org/10.1016/0167-9236(94)00041-2

March, S. T., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision support systems*, *15*(4), 251-266.

Muratet, M., Torguet, P., Jessel, J. P., & Viallet, F. (2009). Towards a serious game to help students learn computer programming. https://doi.org/10.1155/2009/470590

OECD (2005), Improving Financial Literacy: Analysis of Issues and Policies, OECD Publishing, Paris, https://doi.org/10.1787/9789264012578-en.

Peffers K, Tuunanen T, Rothenberger MA, Chatterjee S (2007) A design science research methodology for information systems research. J Manag Inf Syst 24(3):45–77. https://doi.org/10.2753/MIS0742-1222240302

Prensky, M. (2006). Don't bother me, mom, I'm learning!: How computer and video games are preparing your kids for 21st century success and how you can help!. St. Paul: Paragon house.

Rai, K., & Yadav, S. D. M. (2019). Determinants of financial literacy: A study among working women in Delhi. Vivekananda journal of research, 8(1), 194-213.

Rankin, J. R., Sampayo Vargas, S., & Taylor, P. F. (2009). Testing metaphorical educational FPS games. International Journal of Computer Games Technology, 2009(1), 456763. https://doi.org/10.1155/2009/456763

Rodrigues, L. F., Oliveira, A., Rodrigues, H., & Costa, C. J. (2019). Assessing consumer literacy on financial complex products. Journal of Behavioral and Experimental Finance, 22, 93-104.

Rydberg, T. H. (1997). The normal inverse Gaussian Lévy process: simulation and approximation. Communications in statistics. Stochastic models, 13(4), 887-910. https://doi.org/10.1080/15326349708807456

Shepherd, J. J., Doe, R. J., Arnold, M., Cheek, N., Zhu, Y., & Tang, J. (2011, March). Lost in the middle kingdom: a second language acquisition video game. In Proceedings of the 49th Annual Southeast Regional Conference (pp. 290-294). https://doi.org/10.1145/2016039.2016114

Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. British journal of educational technology, 43(4), 540-560. https://doi.org/10.1111/j.1467-8535.2011.01197.x

Shute, V. J., Ventura, M., & Bauer, M. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In Serious games (pp. 317-343). Routledge. https://doi.org/10.4324/9780203891650-31

Sousa, C. & Costa, C. (2011) Market Game: simulation game for business classes. In Proceedings of the 2011 Workshop on Open Source and Design of Communication (OSDOC '11). Association for Computing Machinery, New York, NY, USA, 83–84. https://doi.org/10.1145/2016716.2016737

Stapley, N. F. (1986). The stock market: A guide for the private investor (3rd ed.). Woodhead-Faulkner.

Susi, T., Johannesson, M., & Backlund, P. (2007). Serious games: An overview.

Tankov, P. (2003). Financial modelling with jump processes. Chapman and Hall/CRC.

Tessema, A. (1989). A stock market game in teaching investments. Journal of Financial Education, 33-37.

Thomas, A., & Spataro, L. (2018). Financial literacy, human capital and stock market participation in Europe. Journal of Family and Economic Issues, 39(4), 532-550. https://doi.org/10.1007/s10834-018-9576-5

Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. EDUCAUSE review, 41(2), 16.

Van Rooij, M., Lusardi, A., & Alessie, R. (2011). Financial literacy and stock market participation. Journal of Financial economics, 101(2), 449-472. https://doi.org/10.1016/j.jfineco.2011.03.006

Watson, W. R., Mong, C. J., & Harris, C. A. (2011). A case study of the in-class use of a video game for teaching high school history. Computers & Education, 56(2), 466-474. https://doi.org/10.1016/j.compedu.2010.09.007

Willis, L. E. (2008). Against financial-literacy education. Iowa L. Rev., 94, 197.

Wood, W. C., O'Hare, S. L., & Andrews, R. L. (1992). The stock market game: Classroom use and strategy. The Journal of Economic Education, 23(3), 236-246. https://doi.org/10.1080/00220485.1992.10844758

Yoong, J. (2011). Financial illiteracy and stock market participation: Evidence from the RAND American Life Panel. Financial literacy: Implications for retirement security and the financial marketplace, 76, 39. https://doi.org/10.1093/acprof:oso/9780199696819.003.0005