# A Case Study of Mathematical Analysis Course for Financial Mathematics Majors Based on STEM Concepts

Fusheng Xie* and Kedian Li [a]

Business School, Shanghai Normal University Tianhua College, Shanghai 201815, China

[a]likd56@126.com
*Corresponding author's e-mail: xfs7002@sthu.edu.cn

**Abstract.** This study delves into the innovative application of STEM education principles within the mathematical analysis curriculum of financial mathematics. The primary objective is to elevate students' capacity to apply theoretical concepts to real-world problems and bolster their problem-solving abilities through the meticulous design and execution of a comprehensive suite of illustrative teaching cases. By conducting an exhaustive analysis of these cases, we underscore the pivotal role that mathematical analysis plays in the case-based pedagogy of financial mathematics. Furthermore, we propose a hands-on teaching approach tailored specifically for financial mathematics education, fostering a deeper engagement and understanding among students.

**Keywords:** mathematical analysis; financial mathematics; STEM

## 1 Introduction

### 1.1 Background to the Study

In today's globalized financial market, there's a rising need for professionals skilled in financial mathematics, which integrates knowledge from mathematics, statistics, finance, and computational science. The 2023 Financial Industry Employment Trends Report indicates a significant fintech talent gap, with a decreased demand for traditional financial roles but an increased demand for tech roles. Financial mathematics education aims to prepare professionals to address real-world financial challenges using interdisciplinary approaches.

The financial mathematics major focuses on equipping students with a strong theoretical background in mathematics and finance, practical software skills for financial operations, and the ability to apply financial tools and quantitative methods to solve complex problems. The curriculum starts with theoretical learning to grasp market principles and analytical techniques, followed by practical training to develop skills in mathematical modeling, data analysis, and risk management. This prepares students for various financial industry roles, such as investment banking and risk management, aligning with industry needs.


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Mathematical analysis is crucial for financial mathematics students as it underpins advanced coursework, provides essential tools for financial problem-solving, and hones critical thinking and adaptability—key for navigating the dynamic financial landscape.

### 1.2 Purpose and Significance of the Study

This study, rooted in the STEM education framework, aims to highlight the pivotal role of mathematical analysis in the education of financial mathematics majors. By designing and implementing teaching cases, it assesses the effectiveness of mathematical analysis instruction, providing empirical evidence for financial mathematics education. The study integrates mathematical analysis theory with real-world financial issues through case design, enhancing students' practical problem-solving skills. It also fosters communication, collaboration, and interdisciplinary thinking—essential for careers in finance. The research explores innovative teaching strategies, such as project-based learning through case design, to increase student engagement and interest. Moreover, it aims to improve students' market sensitivity and practical skills by exposing them to authentic financial challenges. The findings offer educators and policymakers insights into the effectiveness of mathematical analysis in professional financial mathematics education, promoting interdisciplinary education to meet the demands of the modern financial market.

### 1.3 Research Methodology and Thesis Structure

The study utilizes qualitative research methods, particularly case studies, to deeply analyze the application of mathematical analysis in financial mathematics education. It includes four steps: a literature review to understand the theoretical and practical applications of mathematical analysis, the design of teaching cases based on literature findings, the implementation and evaluation of these cases using quantitative and qualitative methods, and the drawing of conclusions with pedagogical recommendations. The thesis is structured into six parts: an introduction outlining the study's background, purpose, and methodology; a theoretical foundation and literature review; principles and methods for designing STEM-based teaching cases; detailed design and implementation of teaching cases with real-world financial applications; an evaluation and discussion of case effectiveness; and a conclusion with recommendations based on research findings.

## 2 Rationale and Literature Review

### 2.1 The STEM Framework and Professional Education in Financial Mathematics

STEM education, recognized for its interdisciplinary approach since the 1950s, has been widely adopted by the National Science Foundation (NSF) to describe activities

integrating Science, Technology, Engineering, and Mathematics. [1] This model promotes practical problem-solving and real-world application, which is crucial for financial mathematics education. It aims to develop professionals with a strong foundation in mathematics, economics, and finance, along with technical skills in software and computational tools. [2]

### 2.2 Applications of Mathematical Analysis in Financial Mathematics

Mathematical analysis is vital for financial mathematics, with key applications including function modeling for economic analysis, limit theory for economic growth, derivatives for variable relationships, differential equations for complex financial systems, and probability statistics for financial quantification. These tools are essential for financial modeling, risk assessment, and asset pricing. [3][4][5][6]

### 2.3 Literature Review of Teaching Case Design and Implementation

Case teaching, a student-centered method, combines theory with practical scenarios to enhance students' problem-solving abilities. Studies by Zhao Shu et al. (2016) [7], Lei Changhai et al. (2023) [8], and Jin Radium et al. (2020) [9] have enriched the understanding of case teaching, emphasizing authenticity and interdisciplinary application. Research also highlights the need for a comprehensive curriculum that fosters innovation and practical skills in financial mathematics.

## 3 Principles and Methods of Teaching Case Design Based on STEM Concepts

### 3.1 Principles of Teaching Case Design

To effectively integrate case-based teaching in financial mathematics education, the following principles should guide the design process:

(1) Relevance. Select cases that clearly connect to the learning objectives and facilitate understanding of key concepts.

(2) Simplicity. Choose cases that are accessible and straightforward for students to engage with, avoiding overly complex scenarios.

(3) Efficiency. Design cases that are concise and to the point, ensuring they fit within the constraints of class time.

(4) Interest. Use cases that are engaging and stimulate student curiosity to enhance learning motivation.

(5) Effectiveness. Ensure cases lead to a deeper understanding and practical application of theoretical knowledge.

### 3.2 Design of Case Teaching Mode

The case teaching mode should integrate STEM elements and emphasize a cyclical learning process involving pre-class preparation, in-class interaction, and post-class consolidation. This approach enhances student interest and ensures a thorough grasp of key concepts.[10]

(1) Preparation. Teachers provide relevant teaching videos and task sheets to stimulate student interest and prepare them for class discussions.

(2) In-Class. Teachers integrate mathematical concepts, technology, and engineering thinking to solve problems through discussions and reflections.

(3) Consolidation. Post-class activities encourage reflection and extension exercises that include mathematical modeling and real-world problem-solving to deepen understanding and apply learning.

This structured approach not only helps students master scientific knowledge but also teaches them to apply mathematical and technological skills to practical challenges.

## 4 Teaching Case Design and Implementation

### 4.1 A Case of Functions in Economics and Finance

This case explores the relationship between price and quantity in a bakery's bread sales. Students will analyze how changes in price affect demand and supply, using data to model these functions and predict outcomes. The goal is to understand the impact of pricing strategies on business revenue.

Case 4.1 Suppose we live in a town where there is a single bakery that offers one type of bread. The bakery has a fixed price for its bread, but the quantity of bread demanded by customers varies with the price. The bakery wants to know how much bread customers will buy at different price levels so that it can develop an appropriate pricing strategy. Obtaining past supply and demand data is shown in Table 1.

**Table 1.** Demand and Supply Data Table

| Price (yuan/unit) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Demand (units) | 98 | 96 | 94 | 92 | 90 | 88 | 86 | 84 | 82 | 80 | 78 | 76 | 74 | 72 | 70 | 68 | 66 | 64 | 62 | 60 |
| Supply ( units) | 53 | 56 | 59 | 62 | 65 | 68 | 71 | 74 | 77 | 80 | 83 | 86 | 89 | 92 | 95 | 98 | 101 | 104 | 107 | 110 |

### 4.2 Example of the Second Important Limit Formula in Finance

Students calculate compound interest using the limit formula to understand how interest accrual over time affects investment growth. They will apply this concept to determine the future value of investments with varying compounding frequencies.

Case 4.2 [10] If you receive a state scholarship of $8,000 and invest it in the following manner (at an annual interest rate of r), calculate the sum of the principal and interest income. (1) Calculate the interest on a yearly basis, now save it and try to calculate the sum of principal and interest after one year. (2) What is the sum of principal and interest when interest is settled monthly? (3) What is the sum of the principal and interest when the interest is settled on a daily basis? (4) What is the sum of the principal and interest when the number of interest settlements tends to infinity?

### 4.3 Examples of the use of derivatives in finance

Students analyze marginal cost, revenue, and profit to optimize production levels. The case emphasizes the importance of understanding market dynamics and pricing strategies to maximize profits.

Case 4.3 A factory produces a batch of a product at a fixed cost of $2,000, with the cost increasing by $50 for each additional tone of product. The law of market demand for the product is Q=1100-10P, where Q is the output and P is the price. (1) what is the marginal profit when the output is 100 tones; (2) what is the maximum profit when the output is how many tones?

### 4.4 Examples of Elasticity in Finance

Students assess price elasticity of demand to develop effective pricing strategies that respond to market changes and enhance business competitiveness.

Case 4.4 The demand function for a commodity is Q=100-2P, where Q represents the quantity demanded and P represents the price. (1) Calculate the price elasticity of demand when P=50. (2) What price strategy is appropriate at P =50?

### 4.5 Examples of Integral Applications in Economics and Finance

Students calculate consumer and producer surplus using integrals to understand market efficiency and the distribution of benefits among participants.

Case 4.5 Suppose the market demand function for a good is Q=100-2P, where Q represents the quantity demanded and P represents the price. The supply function is Q=20+3P. calculate consumer surplus and producer surplus.

### 4.6 Example of the Use of Grades in Economics and Finance

Students determine the present value of bonds using series calculations, providing insights into investment valuation and financial planning.

Case 4.6 Suppose a company issues a bond with an annual interest rate of 5%, a face value of $1,000, and a maturity of 10 years. (1) Find the present value of the bond. (2) If the bond is perpetual, what is the present value of the bond?

Each case integrates STEM concepts, applying scientific principles, technological tools, engineering strategies, and mathematical models to solve financial problems, enhancing students' analytical and practical skills in finance.

# 5 Evaluation and Discussion of the Effectiveness of Teaching Cases

## 5.1 Assessment of Teaching Effectiveness

To evaluate the practical impact of the case study teaching method in the field of financial mathematics, we conducted a statistical analysis comparing the academic performance of two student cohorts. Here's a comprehensive account of our findings:

**Data Overview.** Cohort X (Traditional Teaching): Scores represented by [80, 65, 80, 75, 80, 76, 70, 90, 34, 91,73, 76, 78, 62, 89, 56, 77, 67, 85, 88,85,72, 86, 56, 87, 85, 74, 69, 25, 24,88, 60, 84, 20, 78, 88, 88, 82, 91, 79,71, 81, 71] (total 40 data points), reflecting student performance under the traditional teaching approach.

Cohort Y (Case Study Teaching): Scores denoted as [84, 98, 93, 81, 85, 90, 88, 73, 72, 79, 96, 97, 70, 91, 64, 77, 84, 91, 66, 92,92,93, 84, 84, 85, 72, 81, 70, 69, 69,94, 66, 91, 68, 73, 55, 69] (total 37 data points), showcasing student achievement through the case study method.

**Statistical Analysis Results.**

*Mean Comparison.* Cohort X's mean score (Traditional Teaching) is 72.93; Cohort Y's mean score (Case Study Teaching) is 80.70. These results indicate a marked increase in the average performance of students exposed to the case study teaching method, suggesting its significant advantage in enhancing overall academic outcomes.

*Variance and Standard Deviation.* Cohort X's variance and standard deviation is 320.59 and 17.91 respectively, revealing a relatively dispersed score distribution and substantial individual variation under traditional teaching. Cohort Y's variance and standard deviation is 125.88 and 11.22 respectively, demonstrating a more concentrated performance range and reduced variability, signifying a stable and consistent performance boost through case studies.

*T-Test Analysis.* T-statistic is -2.28, with a p-value of 0.0252, confirming a statistically significant difference in the mean scores between the two cohorts at a 95% confidence level. This underscores the effectiveness of the case study teaching method in enhancing student performance.

Beyond the quantitative data, the case study method garnered overwhelmingly positive feedback from students. Since adopting the case study teaching method, the num-

ber of awards won by students in various skills competitions has surged to 75 individuals, nearly doubling the previous tally. This remarkable increase underscores not only the method's effectiveness in honing practical skills but also its broader impact on students' overall competence.

### 5.2 Student Feedback and Analysis

Before case teaching, the instructor received a 92.0000 rating from 27 students. Post-implementation, the rating jumped to 93.5556 from 36 students, showcasing the success of case studies in deepening financial math understanding and boosting students' practical skills and motivation.

Case teaching has provided students with a deeper understanding of financial mathematics concepts such as elasticity, consumer surplus, and producer surplus. It has also equipped them with practical skills in calculating compound interest, maximizing profits, and assessing bond values. Overall, case studies have increased student motivation and practical abilities.

## 6 Conclusion and Recommendations

### 6.1 Conclusions

The study underscores the critical role of mathematical analysis in the education of financial mathematics majors. It provides students with essential mathematical tools for solving financial problems and teaches them to apply these tools in economic and financial modeling. Mathematical analysis lays a solid theoretical foundation for advanced courses and enhances students' logical thinking and problem-solving skills. Case studies integrate theory with real-world financial issues, improving practical problem-solving abilities. The application of the STEM model allows students to synthesize knowledge across science, technology, engineering, and mathematics, facilitating a deeper understanding of financial markets and the development of investment strategies.

### 6.2 Limitations and Future Directions

The study has limitations, including a limited number of cases that may not fully represent the application of mathematical analysis in financial mathematics education. The focus was primarily on case design and implementation, with less exploration of alternative teaching methods. Future research should consider expanding the case studies and investigating diverse teaching approaches to enhance educational outcomes. Collaboration with other institutions could validate the generalizability of the study's findings.

### 6.3 Recommendations

The study offers practical recommendations for educators: emphasize the importance of mathematical analysis as a core course in financial mathematics education. Integrate theory with practical financial issues to strengthen students' practical skills through case studies and other methods. Enhance student engagement by encouraging active participation in discussions and activities to boost interest and involvement. Foster collaboration with other universities and research institutions to introduce high-quality teaching resources and collectively advance financial mathematics education.

The study highlights the significance of mathematical analysis in financial mathematics professional education. By refining teaching methods and strategies, the learning effectiveness and practical application skills of students can be significantly improved. We look forward to more educators engaging in related research to contribute to the field's development. Additionally, we encourage the adoption of the STEM education model to integrate knowledge across disciplines, thereby enhancing the quality and effectiveness of financial mathematics education.

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