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ORGANISING THE TEACHING OF FINANCIAL ELEMENTS IN UPPER-SECONDARY MATHEMATICS THROUGH MATHEMATICAL MODELLING ACTIVITIES

Nguyen Tien Dat
Faculty of Mathematics and Informatics, Hanoi National University of Education, Hanoi city, Vietnam
*Corresponding author: Nguyen Tien Dat, e-mail: ntdat@hnue.edu.vn

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Abstract. In many countries, finance is regarded as a key content area to be integrated into the general education curriculum, particularly in mathematics. Drawing on both international and domestic studies, this paper proposes a pedagogical procedure for teaching financial elements in upper-secondary mathematics through mathematical modelling activities and illustrates its appropriateness with concrete examples.

Keywords: financial elements, financial education, upper-secondary school, mathematical modelling.

1. Introduction

Financial elements have recently been incorporated as a new component in the Vietnamese Mathematics Curriculum 2018 in response to pressing societal needs highlighted by the Organisation for Economic Co-operation and Development's call for improved financial literacy [1], UNESCO's recommendations [2], and the Prime Minister's directive on nationwide financial education embodied in Decision 149/QĐ-TTg on the "National Strategy for Inclusive Finance" [3]. Many countries now embed financial elements in their school curricula [4], and the 2018 Vietnamese framework likewise offers promising opportunities to teach them within mathematics lessons. Early domestic investigations have begun to appear (see more at Tran Thuy Nga [5]; Nguyen Danh Nam et al. [6]; Pham Huyen Trang et al. [7]; Pham Huyen Trang et al. [8]), yet they remain exploratory and have not articulated concrete pedagogies for financial elements in mathematics. Examining Singapore's Mathematics Syllabus and the U.S. Standards for Mathematical Practice, we find evidence that teaching financial elements through mathematical modelling activities is strongly recommended. Empirical work shows that modelling can markedly enhance both problem-solving competence in financial contexts and overall financial literacy. For instance, Sawatzki [9] demonstrated how a taxi-fare task helped students recognize the importance of modelling in financial decision-making, although some students struggled because they lacked prior taxi experience, underscoring the need to choose meaningful financial contexts that reflect learners' backgrounds and interests. In an experimental study with fifty-four Grade 10 students in South Africa, Ekol and Greenop [10] found that those taught compound interest by modelling developed a deeper understanding than peers taught by traditional exposition; they also noted the necessity of ensuring prerequisite skills, as learners stumbled when asked to graph functions, interpret graphs, compute expressions, or factor polynomials during the "rediscovery" phase.

In Vietnam, there have been many research works on the application of mathematical modelling in teaching. For instance, Nguyen Danh Nam [11] outlined a method for designing such activities for high school mathematics. Efforts to foster modelling competence were central to other studies; Nguyen Duong Hoang and Nguyen Hieu Nhi [12] investigated measures for teaching "Sequences - Arithmetic Progression - Geometric Progression" (Algebra and Calculus for 11th grade), while Cao Thi Ha and Nguyen Xuan Dung [13] proposed similar measures for the study of functions in the 10th grade. In specific pedagogical contexts, Bui Anh Kiet and Tran Van Quan [14] employed the mathematical modelling process for "The Law of Cosines and Sines in a Triangle" (Grade 10), and Nguyen Ai Quoc and Nguyen Vu Quynh Nhu [15] illustrated its application in teaching "Solving Triangles" (Grade 10). However, research specifically targeting the integration of financial elements through mathematical modelling in school mathematics remains limited, and existing illustrative examples have received little attention. Specifically, a systematic instructional procedure that guides teachers in designing and implementing finance-related mathematical modelling tasks is still lacking in the Vietnamese context. Consequently, this paper seeks to articulate the distinctive features of teaching financial elements through mathematical modelling activities in the mathematics classroom.

2. Content

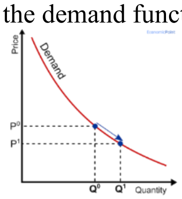
2.1. Mathematical model, mathematical modelling, and the instructional sequence for teaching mathematical modelling

2.1.1. Mathematical model

According to Edwards and Hamson [16], a model is a simplified representation of a real-world system. A mathematical model, specifically, is constructed using mathematical concepts like functions and equations. Its success is judged by its ease of use and the accuracy of its predictions. Blum and Niss [17] state that a real-world situation is first simplified into a "real model". A mathematical model is then created by translating this real model into mathematical language, using objects and relationships that correspond to the original situation. Lesh and Doerr [18] describe a model as a conceptual system used to explain, describe, or construct the behaviour of other systems. A mathematical model focuses on the structural characteristics of these systems and is considered a powerful tool for scientific thinking.

In summary, mathematical models can be expressed through symbols, schematics, graphs, mathematical formulas, and similar forms. For instance, Table 1 lists several representative mathematical models used in finance.

Table 1. Mathematical models used in finance

Objects	Rules	Mathematical models
Listed price (a), promotional discount (b%), amount saved (c)	The discount amount is equal to the list price multiplied by the discount percentage	Formula: $c = a \times b\%$
Assets, liabilities, equity	Assets equal total liabilities and equity	Balance sheet (Example in link https://www.accounting formanagement.org/balance-sheet/)
Price and demand	When the price rises, quantity demanded falls; when the price falls, quantity demanded rises.	Graph of the demand function 

2.1.2. Mathematical modelling

Since the twentieth century, leading educators have strongly advocated the integration of contextual problems into the mathematics curriculum, especially at the primary school level, where they reach the vast majority of students [19]. At the heart of solving such problems lies the process of mathematical modelling. From the very moment the concept of mathematical modelling was introduced, a range of different interpretations emerged, reflecting the divergent viewpoints of various research teams.

For example, the realistic or applied modelling perspective emphasizes solving the original, real-world problem, whereas the epistemological or theoretical perspective places greater emphasis on the development of mathematical theory. Accordingly, corresponding to these different views of mathematical modelling, there exist numerous modelling cycles, each with its own focal point, designed primarily either for research purposes or for classroom application [20].

Building on Pollak [21], Blum [22] and Kaiser-Messmer [23], the educational modelling cycle begins by simplifying a real-world problem to build a real model making key assumptions and identifying critical factors then translating that model into mathematical language to form a mathematical model, working through the mathematics to derive results, interpreting those results back in the original context and validating both the outcomes and the entire modelling process, and repeating some or all of these steps as needed. Cognitive-analysis perspectives have introduced an additional step into the modelling process, the phase in which students construct a *situation model* of the problem context, which is subsequently transformed into a *real model* [20], [24].

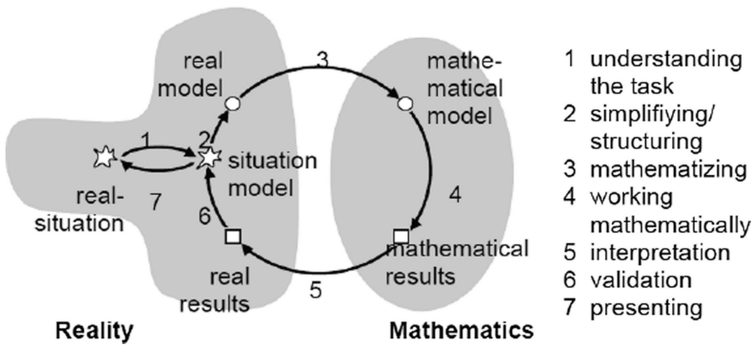


Figure 1. The mathematical modelling cycle (Blum, 2011)

Blum's modelling process [24] comprises seven stages: first, students seek to understand the real-world situation by exploring its context and constructing an initial scenario model; next, they simplify that situation by identifying all relevant variables and selecting those to include in a formal real model; third, they translate this real model into mathematical form choosing or creating representations and describing the relationships among variables in mathematical terms; fourth, they work within the mathematical environment to perform analyses and draw conclusions, returning to the previous stage to revise variables or relationships if the model proves inadequate; fifth, they interpret the mathematical outcomes back in the original context; sixth, they validate and evaluate these results iterating through the modelling stages as needed until the outcomes are satisfactory; and finally, they apply the validated model to other, analogous real-world problems.

Galbraith et al. [25] propose an alternative modelling-cycle approach that centres on learners' ability to solve individual problem situations. This modelling cycle comprises seven interlinked steps: learners begin by understanding, structuring, simplifying, and interpreting the real-world context; next, they state assumptions, build a real model, and mathematise it; then, they carry out the necessary mathematical operations; once results emerge, those mathematical outcomes are interpreted back into the original context; following this, the model and its predictions are compared, evaluated, and validated; if the model is deemed appropriate, learners report and explain their solution; if not, they revisit and revise the entire modelling process adjusting assumptions, representations, or mathematics as needed thus illustrating how a complex real-world situation can be abstracted into a mathematical problem, solved with mathematical methods, and then checked for real-world relevance, looping back through the cycle until a satisfactory solution is achieved.

In summary, depending on their research perspective, scholars delineate the stages of the mathematical modelling process in different ways. What remains consistent is the starting point anchoring the work in a real-world situation and the possible endpoints: either arriving at a mathematical model that satisfactorily addresses that situation or revisiting and revising the model if it proves inadequate. All accounts agree that mathematical modelling is a highly complex, non-linear activity, with its precise sequence of steps shaped by the modeller's individual expertise and judgment.

2.1.3. The instructional sequence for teaching mathematical modelling

According to Le Van Tien [26], teaching mathematical modelling is the pedagogy of constructing mathematical models of real-world situations in response to questions and problems arising from practice. In this approach, learners are first equipped with the requisite theoretical mathematical knowledge and then apply it to solve practical problems or to build models of those real situations. Teaching by mathematical modelling thus follows the very pathway of modelling itself, using the process to surface and impart the specific mathematical concepts needed along the way. Phan Anh Tuyen [27] conceptualizes "teaching mathematical modelling" as a teacher-centered approach in which the instructor constructs and applies mathematical models, bearing full responsibility for conveying the requisite knowledge and skills so that students can understand mathematical concepts, build their own models, and apply them to specific situations. By contrast, "teaching by mathematical modelling" positions the learner as an active participant: students use models as investigative tools to explore and analyze problems, thereby internalizing mathematical concepts and developing related competencies; they generate and test models independently to devise solutions, extract new mathematical insights or properties, and then apply these newly acquired insights to real-world problems.

Viewed together, these perspectives on modelling-based instruction fall into two main types: one treats modelling primarily as a tool for solving practical problems, "teaching modelling", while the other treats modelling as a means of constructing mathematical knowledge, "teaching by modelling". In line with these notions, researchers have put forward a pedagogical framework for teaching mathematical modelling as follows:

According to Le Van Tien [26], the instructional sequence for teaching mathematical modelling unfolds as follows: first, teachers provide theoretical mathematical knowledge, and then students apply that knowledge to solve real-world problems and, in so doing, to construct models of those situations. Alternatively, the reverse sequence of teaching by mathematical modelling begins with a real-world problem that serves as the primary context for learning. Within this context, learners first construct a mathematical model to arrive at a viable solution to the real-world problem. Critically, it is only after this engagement with the problem that the underlying mathematical knowledge to be taught is explicitly identified. Finally, this newly formalized knowledge is consolidated and generalized when students apply it to solve further real-world problems.

Nguyen Danh Nam [28] proposed seven steps for organising mathematical modelling activities in teaching: Step 1: explore, structure, clarify, analyse, and simplify the problem, identifying hypotheses, parameters, and variables within the real-world context; Step 2: establish relationships among the different proposed hypotheses; Step 3: formulate the problem by selecting and using mathematical language to represent the real situation, taking its complexity into account; Step 4: employ appropriate mathematical tools to solve the problem; Step 5: interpret the solution and grasp the significance of the mathematical model in the real-world setting. Step 6: Validate the model by examining its strengths and limitations and checking its logical consistency and optimality. Step 7: communicate, explain, and predict results, then refine the model or construct a more complex one as required by practical needs.

According to Ferri [29], organising mathematical modelling instruction involves two main phases: preparation and planning, and implementation and reflection. In the preparation and planning phase, the teacher should: select a realistic and engaging modelling problem appropriate for the students; solve the problem in advance to anticipate potential student difficulties and prepare differentiated support strategies; specify clear lesson goals, whether it's understanding a mathematical topic, developing modelling skills, or nurturing general competences like teamwork; prepare necessary tools, such as technology, and plan the time for each lesson stage. In the implementation and reflection phase, the teacher should: facilitate the learning environment by ensuring students understand the problem and the structure of the activity; observe and document the different approaches students use while they work; after the lesson, re-examine the objectives and reflect on what worked well and what could be improved. The framework also suggests using tools like "support cards", which provide hints to help students overcome obstacles independently.

2.2. Organising the instruction of financial elements through mathematical modelling activities

2.2.1. Financial elements

To establish a clear conceptual basis, this study draws upon the foundational definitions of its constituent terms. An element is understood as a constituent part of a thing, event, or phenomenon, while finance pertains to the management of monetary resources and their associated flows [30]. Synthesizing these concepts, this paper defines “financial elements” *as the specific components, variables, or considerations within a real-world problem that relate to the management, use, and flow of money. These elements encompass a range of concepts, including cost, price, revenue, profit, interest, savings, debt, and investment.* Several of these financial elements are intrinsically linked to the standard of the high school mathematics curriculum in Vietnam. For instance, concepts of simple and compound interest provide an authentic context for studying geometric progressions and exponential functions. Similarly, the analysis of fixed and variable costs offers a practical application for understanding the limits of functions and the asymptotes of their graphs. In this sense, financial elements provide a rich environment for students to apply mathematical modelling to solve real-world problems.

2.2.2. The instructional procedure for teaching financial elements through mathematical modelling activities

To foreground the role of student activity in mathematics instruction, this paper adopts the view that whether called “teaching modelling” or “teaching by modelling,” modelling-based instruction fundamentally involves the teacher organizing student learning activities around the stages of the modelling cycle. Accordingly, *teaching financial elements through mathematical modelling activities is defined here as the teacher-led use of modelling tasks to address finance-*

related problems, to develop both mathematical and financial knowledge as students build and solve their models under guidance. The knowledge developed through this process is categorised into four types: factual knowledge, procedural knowledge, normative knowledge, and value knowledge [31].

Furthermore, adapted from the work of Le Van Tien [26], Nguyen Danh Nam [28], and Ferri [29], we propose a five-step teaching procedure as follows:

Step 1 – Identify the problem through a financial situation: The teacher presents a finance-related context and the problem that arises within it, ensuring that students clearly understand all financial terms involved (e.g., simple interest, compound interest, revenue, profit, cost, etc.). The instructional goal is to have students establish relationships among the quantities in the situation through formulas, tables, diagrams, etc., as a basis for solving the problem.

Step 2 – Construct a financial-mathematical model: Students list the practical elements: variables (e.g, principal, interest rate, time, interest formula, costs, etc.) and conditions or constraints (e.g., maturity, minimum cost, maximum profit, etc.). Guided by the teacher, they mathematize these elements into equations, diagrams, or tables. "Support cards" (e.g., the compound-interest formula, a profit formula) may be provided if students are stuck, but over-reliance on such hints should be avoided.

Step 3 – Solve the model and check the answer against reality: Students carry out the necessary calculations, solving equations or using technological tools to obtain a result. They then interpret the outcome, compare it with real data, judge the model's reasonableness, and analyze the influence of variables (e.g., how a rate change affects returns, or the penalty incurred for early withdrawal). While students work, the teacher circulates, noting approaches, errors, and difficulties to inform the subsequent whole-class discussion.

Step 4 – Extract mathematical knowledge from the modelling process: Drawing on the results of Step 3, the teacher helps students explore possible applications of their findings. If a concept, formula, or theorem that is part of the syllabus emerges, the teacher formalizes it and aligns it with the curricular content.

Step 5 – Apply the newly learnt knowledge to a new financial situation: Finally, the teacher poses analogous tasks or new financial situations that require students to use the insights gained in Step 4, thereby consolidating both their mathematical and financial literacy.

2.3. Applying the instructional procedure in exemplary teaching scenarios

2.3.1. Teaching the concept of linear inequalities in two variables

The teacher introduces the concept of a linear inequality in two variables, as presented in Chapter II, Lesson 3 of the 10th-grade Mathematics textbook in the "Connecting Knowledge with Life" series. The lesson is anchored in the context of a "trip to the cinema".

Step 1 – Identify or enter the problem through a financial situation. Situation: On International Children's Day (June 1st), a cinema is showing a popular animated film for all audience segments. Two types of tickets are available: type 1 (for children aged 6-13): 50,000 VND/ticket; type 2 (for individuals over 13 years old): 100,000 VND/ticket. The cinema's management requires that the total revenue from ticket sales for this specific screening be at least 20 million VND to avoid a loss. Guiding question: "Given the current economic challenges, how can this cinema avoid financial loss for this particular film screening?".

Step 2 – Construct a financial-mathematical model. A list of fixed data and variable factors is established.

Fixed data: ticket prices for Type 1 and Type 2, and the minimum required revenue (20 million VND).

Variables: the number of Type 1 tickets sold and the number of Type 2 tickets sold. Mathematization: to mathematize the problem, let x be the number of Type 1 tickets sold, and y be the number of Type 2 tickets sold $(x, y \in \mathbb{N})$. The total revenue generated from selling these tickets can be expressed as $50000x + 100000y$. The constraint that this revenue must be at least 20 million VND is modelled by the inequality:

$$50000x + 100000y \geq 20000000$$

Step 3 – Solve the model and check the answer against reality. Students perform calculations to find pairs of (x, y) values that satisfy the condition, such as $(x, y) = (100, 200)$.

Step 4 – Extract mathematical knowledge from the modelling process. The teacher guides students to recognize the mathematical nature of the relationship between x, y, and the total revenue. This relationship is defined by an inequality, which is formally introduced as *a linear inequality in two variables*.

A linear inequality in two variables, x and y, has the general form:

$$ax + by \leq c; ax + by \geq c; ax + by < c; ax + by > c$$

where a, b, c are real numbers, with a and b not simultaneously equal to zero.

Every pair of numbers (x_0, y_0) that makes the inequality $ax + by < c$ a true statement is called a *solution* to the inequality.

Step 5 – Apply the newly learnt knowledge to new financial situations. The teacher presents new problems for students to model or expand their understanding, such as a restaurant's promotional pricing. *New situation:* A restaurant offers special promotional meal sets for summer. Children's Meal Set: For children from 6 to 12 years old, priced at 60,000 VND/set. Adult's Meal Set: For customers over 12 years old, priced at 130,000 VND/set. Condition: To avoid a loss, the restaurant determines that the total revenue from selling the meal sets must be at least 30,000,000 VND. *Questions:* a) Determine the combinations of meal sets (of each type) that must be sold for the restaurant to avoid loss. b) A market survey indicates that the number of Children's Meal Sets sold is always greater than the number of Adult Meal Sets. In this case, what additional condition must the solution satisfy?

2.3.2. Teaching the sign theorem for a quadratic trinomial

The teacher presents the Quadratic Sign Theorem (Lesson 3, Chapter III, The Kite textbook series, Grade 10 Mathematics, Volume 1, first semester) through the situation "Buying sightseeing tickets."

Step 1 – Identify or enter the problem through a financial situation. Situation. "A travel agency announces the ticket price for a sightseeing trip as follows: the first 50 passengers pay 300,000 VND each. If more than 50 people register, the price of every ticket is reduced by 5,000 VND per additional passenger for the entire group. The fixed cost of operating the trip is 15,080,000 VND." Guiding Question: "How many tourists must the company take so that the trip at least breaks even?"

Step 2 – Construct a financial-mathematical model. List the fixed data: the ticket price for the first 50 passengers is 300,000 VND per person, and the fixed cost of the trip is 15,080,000 VND. The variables are the number of additional passengers and the ticket price per person once the group exceeds 50 people. Mathematization: Let x be the number of passengers beyond the first 50 $(x \in \mathbb{N})$. Then the group size is $50 + x$ and the ticket price per person falls to

$300000-5000x$ (VND). *Revenue.* $R(x)=(50+x)(300000-5000x)$. *Profit.* $P(x)=(50+x)(300000-5000x)-15080000$. To avoid a loss, we require $P(x)\geq 0$ i.e.

$$(50+x)(300000-5000x)-15080000\geq 0$$

After simplification, this becomes a quadratic inequality $x^2-10x+16\leq 0$

Step 3 – Solve the model and check the answer against reality. Students' test values: With $x=2;x=8$ the expression $x^2-10x+16=0$ satisfies the requirement. For values of x outside the interval $[2;8]$, e.g. $x=1$ or $x=10$, we obtain $x^2-10x+16>0$. For values of x inside $[2;8]$, e.g. $x=5$ or $x=7$, we obtain $x^2-10x+16<0$. Hence, the company will not incur a loss if it carries between 52 and 58 passengers, inclusive.

Step 4 – Extract mathematical knowledge from the modelling process. The teacher notes that for the quadratic trinomial. $x^2-10x+16$: it has the same sign as its leading coefficient (which is 1) whenever x lies outside the interval between its two roots $x_1=2;x_2=8$; it has the opposite sign of the leading coefficient when x lies between the two roots $x_1=2;x_2=8$. In the general case with x as a real number, the above conclusion still satisfies (GeoGebra can be used for illustration). From that point, we could guess that

> For any quadratic $f(x)=ax^2+bx+c(a\neq 0)$ with discriminant $\Delta=b^2-4ac$.
>
> If $\Delta>0$ then $f(x)$ has two distinct real roots $x_1,x_2(x_1<x_2)$. From there $f(x)$ has the same sign as the leading coefficient a inside the interval $(-\infty;x_1)$ and $(x_2+\infty)$; the opposite sign for all x in $(x_1;x_2)$.

Step 5 – Apply the newly learnt knowledge to new financial situations. The teacher could extend the problem proposed (similar situations): "An Binh Travel announces the ticket price for a sightseeing tour as follows: for the first 10 passengers, the price is 800,000 VND per person. If more than 10 people register, the price for each passenger is reduced by 10,000 VND for each additional person. The fixed operating cost is 700,000 VND per passenger. What is the maximum group size the company can take without incurring a loss?".

3. Conclusions

This paper has addressed the pressing need for a structured pedagogy to teach financial elements in the Vietnamese upper-secondary mathematics curriculum. By synthesizing international and domestic research on mathematical modelling, we have constructed and proposed a practical five-step instructional procedure designed to guide teachers in this endeavor. The viability and applicability of this procedure were illustrated with two examples, which showed how core mathematical concepts specifically linear and quadratic inequalities—can be effectively taught through engaging, real-world financial contexts such as break-even analysis and profit optimization.

While this study provides a robust theoretical framework and concrete examples, future research should focus on its empirical validation. Classroom-based intervention studies are recommended to measure the effectiveness of this procedure on students' learning outcomes, modelling competencies, and overall financial literacy. Further investigations could also explore the adaptations of this procedure for other mathematical topics and different educational levels.

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