

INTEGRATED TEACHING OF MATHEMATICS ON THE TOPIC OF FINDING MAXIMUM AND MINIMUM VALUES USING DERIVATIVES

Dao Thi Hoa^{1*}, Ngo Thi Tu Quyen²

¹Hanoi Pedagogical University 2

²TNU - University of Education

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Received:	15/8/2025	In the context of implementing general education reforms, mathematics, as a fundamental and instrumental subject, provides numerous opportunities for applying integrated teaching approaches. This article provides a systematic overview of key theoretical issues related to integrated teaching in mathematics, including its concept, forms, factors influencing effectiveness, and its specific application in high school mathematics education. Based on this foundation, the paper proposes two specific measures for implementing integrated teaching in mathematics through the topic of Finding maximum and minimum values using derivatives. Measure 1 involves designing integrated teaching situations aimed at knowledge formation, corresponding to the first stage of the integrated teaching process - the knowledge formation stage. Measure 2 focuses on developing integrated exercises, corresponding to the second stage - practice and application of knowledge. These measures are intended to effectively assist teachers in organizing integrated teaching activities in mathematics, thereby enhancing students' ability to make connections across disciplines and apply mathematical knowledge to practical problem-solving.
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DAY HỌC TÍCH HỢP TRONG MÔN TOÁN QUA CHỦ ĐỀ TÌM GIÁ TRỊ LỚN NHẤT, NHỎ NHẤT BẰNG ĐẠO HÀM

Đào Thị Hoa^{1*}, Ngô Thị Tú Quyên²

¹Trường Đại học Sư phạm Hà Nội 2

²Trường Đại học Sư phạm – ĐH Thái Nguyên

THÔNG TIN BÀI BÁO		TÓM TẮT
Ngày nhận bài:	15/8/2025	Thực hiện công cuộc đổi mới giáo dục phổ thông, môn Toán là môn học công cụ, có nhiều cơ hội thực hiện định hướng dạy học tích hợp. Bài viết hệ thống một số vấn đề lý luận cơ bản về dạy học tích hợp trong môn Toán như: khái niệm dạy học tích hợp, các hình thức dạy học tích hợp, yếu tố ảnh hưởng đến dạy học tích hợp, dạy học tích hợp trong môn toán Trung học phổ thông. Từ đó, bài báo đề xuất hai biện pháp dạy học tích hợp trong môn Toán qua chủ đề Tìm giá trị lớn nhất nhỏ nhất bằng đạo hàm. Biện pháp 1, thiết kế tình huống dạy học tích hợp hình thành kiến thức mới, tác động vào bước đầu tiên của quá trình dạy học tích hợp là giai đoạn hình thành kiến thức mới. Biện pháp 2, xây dựng bài tập tích hợp, tác động vào giai đoạn thứ hai của quá trình dạy học tích hợp là giai đoạn luyện tập, vận dụng kiến thức. Các biện pháp này hỗ trợ hiệu quả cho giáo viên trong việc triển khai dạy học tích hợp trong môn Toán, nâng cao khả năng của học sinh trong việc áp dụng kiến thức toán học vào giải quyết các vấn đề thực tế và tạo ra những kết nối giữa các môn học.
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* Corresponding author. Email: daothioa@hpu2.edu.vn

1. Introduction

In the global context, the integrated teaching approach has become a prevailing trend in curriculum design, content selection, and classroom organization. In Vietnam, integrated teaching is one of the core orientations of the 2018 General Education Curriculum, aiming to shift the educational focus from knowledge transmission to the development of students' competencies and qualities. In the general education curriculum, Mathematics holds a significant position as it serves as a fundamental knowledge for learning other subjects and for practical applications in everyday life [1]. The topic of Finding the maximum and minimum values using derivatives provides significant potential for integrated teaching: intra-disciplinary integration (Geometry, Algebra), cross-disciplinary integration (Physics, Chemistry, Biology), and interdisciplinary or transdisciplinary integration (through practical applications such as cost optimization). Given these connections, this topic presents a strong opportunity for integrated teaching. Numerous studies have examined integrated teaching [2]–[10]. These studies primarily focus on theoretical foundations and general solutions for integrated teaching, covering a broad scope. However, among the integrated teaching studies we have reviewed, no research specifically addresses the implementation of integrated teaching in high school Mathematics through the topic of finding maximum and minimum values using derivatives. From this practical basis, this study aims to propose several integrated teaching methods in Mathematics through the topic "Finding the maximum and minimum values using derivatives", thereby contributing to improving teaching effectiveness and developing students' competencies at the upper secondary level.

2. Methodology

In this study, we employed a theoretical research method to analyze and synthesize documents related to integrated teaching, finding maximum and minimum values, derivatives. From the results of the analysis, we propose several integrated teaching measures in mathematics through this topic. Data were collected through two main approaches: (1) Theoretical document analysis: Analyzing and synthesizing theoretical documents and previous studies on integrated teaching to propose pedagogical measures. (2) A priori comparison: Comparing teaching situations in previous studies on teaching the concepts of maximum and minimum values and derivatives to construct suitable teaching situations and illustrative examples.

3. Findings and discussion

3.1. Fundamental theoretical issues in integrated teaching

3.1.1. Concept

Integration is the combination and unification of different components into a cohesive whole [11]. Integration in education is a method of presenting scientific concepts and principles that expresses the fundamental unity of scientific thought. It helps avoid an overly strong or premature emphasis on the differences between various scientific fields [12].

Integrated teaching is an instructional approach that enables students to develop the ability to synthesize and apply knowledge, skills, from multiple fields to effectively solve problems in learning and life. This process takes place simultaneously with the acquisition of knowledge and the development of skills [13]. Integrated teaching has significant meaning: It contributes to achieving the comprehensive educational goals of general education; satisfies the intrinsic connections between scientific knowledge; helps reduce the academic burden on students; and maximizes the personal growth and development of each student [14].

3.1.2. Forms of integrated teaching

Based on [15], there are different perspectives on the forms of integrated teaching, such as those of D'Hainau, Xavier Rogier, Susan M. Drake. These perspectives share common elements,

including intra-disciplinary integration prioritizes the content of a single subject while maintaining distinct subject boundaries. Multi-disciplinary integration keeps subjects separate but share common themes or issues. Interdisciplinary integration, subjects are interconnected through shared themes, issues, cross-disciplinary standards, ... major concepts, and overarching ideas. Transdisciplinary integration does not start with subjects or common concepts and skills but rather with real-life contexts and students' interests: the core knowledge from multiple disciplines is structured around a real-life context, linked to students' needs, helping them develop essential skills for diverse situations.

3.1.3. Factors affecting integrated teaching

Based on the study of George and Alexander [16], there are four factors affecting integrated teaching: Environmental factors include issues such as time, resources, and facilities. Social factors refer to the support from authorities and colleagues for integrated teaching, as well as students' reactions. Curricular factors encompass the volume of knowledge, teaching standards, assessment methods, and teacher professional development. Personal factors involve teachers' beliefs and experiences related to integration.

3.2. Integration in Mathematics teaching

3.2.1. The model of Mathematics and Science

Recent research has increasingly focused on identifying the integration of mathematics and sciences through theoretical models. The theoretical model of Integration of Mathematics and Science Education has identified types of interactions between mathematics and science. These types include Math for math: M; Math – Science context: Ms; Math and Science: MS; Science – apply Math: Sm; Science for Science: S. Brown and Wall [2] refined these types into a continuum, including mathematics for the sake of mathematics, mathematics for the sake of science, mathematics and science in concert, science for the sake of mathematics, and science for the sake of science. Recent theoretical models have followed a similar continuum with slight modifications. However, only the Berlin – White Integrated Science and Mathematics Model, abbreviated as BWISM (Figure 1), uniquely describes the core of this continuum, mathematics and science (Math and Science: MS) [3].

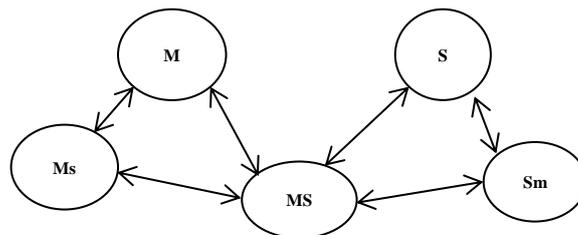


Figure 1. BWISM model

The Berlin-White Integrated Science and Mathematics Model has been recognized in both the science and mathematics education communities [3]. It reflects and integrates multiple perspectives, including empirical research, viewpoints from the mathematics and science communities, curriculum studies and development projects, as well as classroom practices.

3.2.2. Integrated teaching in Mathematics at the high school level

The contents of mathematics education in the 2018 Mathematics curriculum at the high school level [13] reflect integration [10] based on the models presented in Section 3.2.1, as follows: (1) The curriculum maintains a coherent structure from grades 10 to 12, illustrating horizontal and vertical connections among knowledge units (intra-disciplinary integration). This characteristic

corresponds to “Math for Math: M”, where mathematics develops internally for its own sake. (2) Mathematics serves as a foundational discipline supporting subjects such as Physics, Chemistry, Biology, Geography (multi-disciplinary integration). This reflects both “Math–Science context: Ms” and “Science–apply Math: Sm”, since mathematics provides essential tools for science learning while scientific contexts in turn strengthen mathematical understanding. (3) Students are encouraged to use mathematical knowledge together with concepts from other subjects to address real-life problems and participate in experiential activities (interdisciplinary/ transdisciplinary integration). This fits in with “Math and Science: MS”, “Science for Science: S”, as knowledge from different fields together contributes to the advancement of science.

In this article, the forms of intra-disciplinary, multi-disciplinary, interdisciplinary, and transdisciplinary integration in Mathematics teaching, as examined in study [10], are specifically applied through the measures and illustrative examples presented in Section 3.3.

3.3. Integrated teaching in Mathematics through the topic: Finding maximum and minimum values using derivatives

The teaching process of mathematics topics in secondary schools is usually carried out according to the sequence: constructing new knowledge → practicing and applying. Accordingly, the basis for proposing integrated teaching measures in mathematics lies in this process, together with the theoretical issues of concepts, forms, and influencing factors of integrated teaching presented above.

Measure 1: Designing integrated teaching situation for introducing new knowledge

Objectives: Influence the initial stage of the teaching process, namely the knowledge formation stage; Impact on one of the four factors affecting integrated teaching (provide teachers with ideas and methods for integrated teaching in the knowledge formation stage - curriculum factor); Create opportunities for students to engage in thinking tasks with integration elements, applying their accumulated knowledge and skills from different subjects or real-life contexts to acquire new knowledge.

Content: According to Nguyen [1], knowledge formation is the process where students engage in thinking, interaction, and experience to develop an understanding of knowledge. Teaching scenarios are situations where the teacher’s role is explicitly demonstrated to facilitate students’ learning of a particular concept. According to Trinh et al. [9], an integrated teaching scenario in Mathematics is one where the teacher organizes and guides students to apply integrated mathematical knowledge to solve problems, thereby fostering and developing essential qualities and competencies. Thus, an integrated teaching scenario for introducing new knowledge is a situation designed by the teacher to encourage students to think critically and synthesize knowledge and skills from different subjects or real-life experiences to solve problems, thereby forming new knowledge.

Implementation Steps: (1) *Identify objectives and content.* Based on the lesson’s expected outcomes and students’ characteristics, teachers determine the teaching objectives and the new knowledge content to be developed for students. (2) *Search for or develop an integrated model.* Teachers explore the connections between the new mathematical knowledge and other subjects or real-life contexts through textbooks, reference materials, and personal experience. They may also consult colleagues to search for or develop integrated models. These models serve as a foundation for developing integrated learning situations. (3) *Develop an integrated learning situation.* From the models identified in Step 2, teachers analyze, select, and refine an integrated learning situation. The situation should be clear, concise, suitable for students’ level and lesson content, provide integrated information, and be connected to real life. (4) *Proposed plan for organizing teaching.* Teachers design a plan for implementing the integrated learning situation, including assigning tasks to students, monitoring, supporting students in completing tasks, organizing student presentations and discussions, and concluding with the evaluation and assessment of students’ outcomes.

Example: Designing an integrated teaching situation to form knowledge of Finding maximum and minimum values using derivatives

(1) Identify objectives and content

- Objective: Enable students to derive the steps for finding maximum and minimum values from an integrated learning situation.

- Knowledge: Steps to determine maximum and minimum values using derivatives.

(2) Search for or develop an integrated model

Referring to [17] - [20], model 1 is given as follows: A function represents the concentration of oxygen in a lake when a certain amount of organic waste is discharged into it (the decomposition of organic waste in the water consumes the dissolved oxygen). It is necessary to determine the time at which the oxygen concentration in the water reaches its maximum and minimum values. Models 2, 3, and 4 are all related to designing an open-top rectangular box from a sheet of cardboard with given dimensions. The task is to determine the maximum volume of the box. Alternatively, other models may be considered, such as model 5: In physics, the formula for the height $h(t)$ of an object thrown vertically upward from the ground (neglecting air resistance) is given by $h(t) = v_0t - \frac{1}{2}gt^2$ where v_0 is the initial velocity (m/s), t is the time (s), and g is the acceleration due to gravity (m/s^2). A student throws a ball vertically upward from the ground with an initial velocity of $v_0 = 8 \text{ m/s}$. Using the acceleration gravity $g = 9.8 \text{ m/s}^2$, find the maximum height (m) the ball reaches.

(3) Develop an integrated learning situation

- Analyzing the models: Models 1 - 4 have already been used in the Grade 12 Mathematics textbooks. Model 5 requires students to integrate knowledge from Mathematics (quadratic functions, derivatives), Physics (velocity, acceleration gravity), and Physical Education (soccer) to solve a real-world problem. Model 5 differs from the models in the textbook series and clearly demonstrates the element of integration.

- Selecting/Building the scenario: Based on the above analysis, we chose situation 5 to facilitate students' knowledge construction.

(4) Proposed plan for organizing teaching

- Require students to complete the task in pairs on the learning worksheet.

- Guidance for students in carrying out the task: Identify mathematical problem from practical problem; solve mathematical problem (**find the domain of the function $h(t)$, compute the derivative of $h(t)$ and determine the value(s) of t such that $h'(t) = 0$, construct the variation (monotonicity) table, draw a conclusion**); answer questions for practical problem.

- Student Presentation: A representative from one group presents their findings while other groups provide feedback and additional insights.

- Teacher's Conclusion: From the mathematical solution in the above situation, generalize the procedure for finding the maximum and minimum values using derivatives; clarify and finalize students' responses, emphasizing the key steps in determining maximum and minimum values of a function using derivatives; inform students the significance of knowledge about finding maximum and minimum values using derivatives in solving practical problems.

Based on [10], it can be seen that interdisciplinary/transdisciplinary integration was employed in the example of measure 1. Students use knowledge from Mathematics, Physics, and Physical Education to solve real-life situations, thereby constructing new knowledge.

Measure 2: Developing Integrated Exercises

Objectives: Focus on the second stage of the teaching process: Practice/Application; Address one of the four key factors influencing integrated teaching (Curriculum Factor) by providing teachers with ideas and methods for implementing integrated teaching during the practice/application stage; Create opportunities for students to engage in learning tasks that incorporate integration, allowing them to synthesize and apply knowledge and skills from multiple subjects or real-life contexts for practice and application.

Content: An exercise is a defined information system consisting of conditions and requirements given in the teaching process, requiring learners to provide an answer [21]. Based

on research on the concepts of exercises and integration, we define integrated exercises as tasks that require learners to apply knowledge and skills from multiple disciplines or learning areas to solve or explain real-life or academic problems. Integrated exercises play a crucial role in mathematics education as they: help students grasp fundamental mathematical concepts; reinforce and deepen knowledge; enable students to see the significance and connections between mathematics, other scientific disciplines, and real-life applications; Develop students' ability to connect and apply mathematical knowledge to solve problems in mathematics, real-life situations, and across other disciplines; enhance students' general social knowledge.

Implementation Steps: (1) *Selecting mathematical knowledge for developing integrated exercises:* Choose mathematical concepts that are not only academically significant but also have real-world applications and relevance to other scientific fields. (2) *Defining the objectives of the integrated exercise:* Ensure that the exercise aligns with the objectives and learning outcomes specified in the 2018 Mathematics General Education Curriculum. (3) *Developing integrated exercises according to the defined objectives:* Teachers may select from available integrated exercises in reference materials or design new ones. When creating new integrated exercises, the following approaches can be used: Modifying data (numerical values, objects) from an existing problem; Generalizing the original problem; Reversing the given information and the required outcome of the original problem; Adding real-world or interdisciplinary elements to problems that are purely mathematical; Designing exercises based on real-life problem-solving needs.

For example, consider the following original problem: "A ribbon is 130 cm long. It is used to wrap around a cylindrical gift box. When wrapping, 10 cm of the ribbon is used to tie a bow on top of the box (Figure 2). What is the maximum possible volume of the gift box that can be wrapped with the ribbon?"



Figure 2. Gift box ribbon

This problem requires students to integrate knowledge from Mathematics (volume, cylinder, maxima and minima, derivatives) and Technology (gift-wrapping techniques) in order to solve a real-life problem (interdisciplinary/transdisciplinary integration).

New problems can be constructed as follows:

+ *Problem 1 (Similar problem):* A ribbon of length 160 cm is given. It is used to wrap around a cylindrical gift box. When wrapping the gift, 15 cm of the ribbon is used to tie a bow on the lid of the box (Figure 2). Determine the maximum volume of the gift box that the given ribbon can wrap around.

+ *Problem 2 (Generalized problem):* A ribbon of length l is given. It is used to wrap around a cylindrical gift box. When wrapping the gift, $\frac{l}{10}$ of the ribbon is used to tie a bow on the lid of the box (Figure 2). What is the maximum volume of the gift box that the ribbon can wrap around?

+ *Problem 3 (Inverse Problem):* A cylindrical gift box has a volume of 3.14 cm^3 , and a ribbon is used to both wrap around the box and tie a bow (Figure 2). Find the shortest possible length of the ribbon, given that the part used to tie the bow is 10 cm.

(4) *Analyze, edit, and finalize the exercises.* After constructing the exercises, it is necessary to review their accuracy, scientific validity, feasibility, and make content revisions if needed.

Illustration of some integrated exercises on finding maximum and minimum values using derivatives:

(1) *Selecting mathematical knowledge to construct integrated exercises:* The knowledge of "finding maximum and minimum values using derivatives". (2) *Determining the objectives of the integrated exercises:* Apply knowledge and skills related to finding maximum and minimum values using derivatives to solve problems involving integration with other elements. (3) *Constructing integrated exercises according to the defined objectives.*

Below are some integrated exercises under the topic finding maximum and minimum values using derivatives.

Intra-disciplinary integrated exercises

Exercise 1. Given the square ABCD with side length a , arc BD is a quarter-circle centered at A with radius AB, contained within the square. The tangent at M of arc BD intersects segment CD at point P and segment BC at point Q. Determine the position of point M such that the length of segment PQ is minimized.

Exercise 2. Given an equilateral triangle ABC with side length a . Draw rays Aa, Bb, and Cc, all in the same direction and perpendicular to plane (ABC). On ray Aa, take point A'; on ray Bb, take point B' such that $AA' = BB' = 2a$. Determine the position of point C' on ray Cc so that the area of triangle A'B'C' is minimized.

Exercise 3. Given a pyramid S.ABCD with a rhombus as its base ABCD, where each side of has length a and $SA = SB = SC = a$. Determine the length of diagonal AC of the base so that the volume of the pyramid is maximized.

Exercise 4. Given a sphere with radius 1. Find the minimum volume of a regular tetrahedral pyramid that circumscribes the sphere.

Multi-disciplinary integrated exercises (including Physics and Chemistry)

Exercise 5. A converging lens has a focal length of $f = 20$ cm. A light emitting object AB is placed in front of the lens, perpendicular to the principal axis, forming a real image A'B'. Keeping the object AB fixed, the lens is moved away from the object while keeping the principal axis unchanged. What should be the distance between the object AB and the lens so that the distance between the object and the image A'B' is minimized?

Exercise 6. An object of mass m is pulled along a horizontal plane by a force \vec{F} that forms an acute angle α with the horizontal (Figure 3). The coefficient of friction between the object and the surface is μ . Given that the object moves at a constant velocity, determine the angle α such that the force \vec{F} is minimized.

Exercise 7. Write the reaction equation to form Nitrogen dioxide from Nitrogen monoxide and oxygen. Determine the oxygen concentration for the greatest reaction rate.

Interdisciplinary/transdisciplinary integration exercises (applying knowledge from multiple subjects to solve real-life situations)

Exercise 8. A family plans to build a parabolic gate that is 8 meters high and 6 meters wide, then install a rectangular door inscribed within the parabola. Determine the dimensions of the gate so that the walkway area is maximized. (Integration of knowledge from Mathematics (quadratic functions, parabolas, inscribed rectangles, area, optimization, derivatives) and Technology (techniques of designing and constructing gates, calculation of walkway areas) to solve real-world problems).

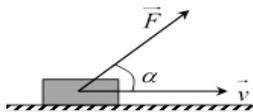


Figure 3. Pulling force model

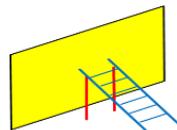


Figure 4. Ladder model



Figure 5. Pate box model

Exercise 9. When using a ladder leaning against a wall, to ensure occupational safety (by minimizing the risk of slipping and making the ladder short enough for easy movement), a worker needs to place the ladder so that it can rest on both the wall and the ground, passing over a support post. The support post of height $\sqrt{3}$ m, which is placed parallel to and at a distance from the wall $\frac{1}{3}$ m (Figure 4). Find the minimum length of the ladder. (Integration of knowledge from Mathematics (right triangles, Thales' theorem, optimization, derivatives), Technology (techniques of designing ladder structures leaning against walls), and Civic Education (situations related to occupational safety) to solve real-world problems).

Exercise 10. Ha Long Canned Food Joint Stock Company plans to manufacture a cylindrical can for storing beef pate (Figure 5). Given that the net weight of each can is $m = 150$ grams and

the pâté has a density of $D = 1.05 \text{ kg/l}$, determine the dimensions of the can that minimize the material cost for production. The net weight refers to the weight of the product excluding packaging. (Integration of knowledge from Mathematics (volume, total surface area, cylinders, optimization, derivatives), Physics (mass, density), Technology (techniques of designing product packaging, calculation of fuel costs) to solve real-world problems).

According to [10], the examples in measure 2 illustrate the application of a wide range of integration forms: intra-disciplinary, multi-disciplinary, interdisciplinary, and transdisciplinary.

Also based on [10], it can be seen that both measures 1 and 2 may employ intra-disciplinary, multi-disciplinary, interdisciplinary, transdisciplinary integration. However, the integrated situations in measure 1 are intended to construct new knowledge, but the new knowledge may be difficult and unfamiliar to students. Therefore, such situations are usually designed to be close and familiar, enabling students to solve them easily and thereby acquire new knowledge. The integrated problems in measure 2 aim at applying knowledge and thus often vary in their level of difficulty.

4. Conclusion

Integrated teaching is one of the key methodological orientations that plays a crucial role in implementing the 2018 General Education Curriculum. The proposed pedagogical measures for integrated teaching in Mathematics impact two stages of the teaching process: knowledge formation and practice/application. Measures 1 and 2 can be applied in lessons aimed at knowledge formation. Measure 2 is also suitable for practice, review, and specialized topics. Each measure clearly defines its objectives, content, implementation steps, and illustrative examples. These approaches can help teachers effectively apply integrated teaching strategies in Mathematics, contributing to the successful implementation of the 2018 curriculum reform.

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