

# *Exploration of the Cultivation Path of Computational Thinking in Calculus*

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**Abstract:** In the era of artificial intelligence and big data, computational thinking, as a way of solving problems and processing information, is particularly important for the development of college students. Computational thinking has become a basic thinking skill that every college student should possess. Calculus, as an important foundation in various fields such as modern science, technology, engineering, and economics, is an important platform for cultivating computational thinking. This article lists the computational thinking contained in calculus courses and explores how to cultivate students' computational thinking in calculus teaching. This article points out that cultivating computational thinking in calculus courses can not only enhance students' problem-solving ability and innovative thinking, but also strengthen their interdisciplinary application ability and rigorous mathematical literacy. At the same time, the cultivation of this kind of thinking also helps promote students' personal growth and development, laying a solid foundation for their future career.

## **1. Introduction**

The concept of computational thinking originated in March 2006, when Professor Jeannette M. Wing, the director of the Department of Computer Science at Carnegie Mellon University in the United States, presented it in the authoritative computer journal Communications of the ACM and defined computational thinking. Professor Wing believes that computational thinking is a series of thinking activities that apply fundamental concepts of computer science to solve problems, design systems, and understand human behavior, covering the breadth of computer science; She believes that computational thinking is a fundamental skill for everyone, not just for computer scientists. Every child should also learn computational thinking while developing analytical skills [1].

From the perspective of the current education status of computational thinking at home and abroad, the cultivation of computational thinking has been included in the information technology curriculum standards of compulsory education in primary and secondary schools. In the university education stage, computational thinking is a teaching task of computer courses in universities. However, Weintrop et al. pointed out that computational thinking should be mutually beneficial and symbiotic on the basis of practicing the concepts and knowledge of computer science, mathematics, and science [2-4]. It can be seen that mathematics is indispensable in cultivating computational thinking.

## 2. How to cultivate computational thinking in calculus

Calculus is an important mathematical discipline with high abstraction, rigorous logic, and wide applicability, and is a compulsory course for students in higher education institutions.

There is a mutually reinforcing relationship between computational thinking and calculus. On the one hand, calculus provides a solid theoretical foundation and rich mathematical tools for computational thinking. For example, concepts such as limits, derivatives, and integrals in calculus provide important mathematical foundations for algorithm design and data analysis. On the other hand, computational thinking has also driven the development of calculus. With the continuous advancement of computer technology and the continuous improvement of computing power, more and more complex mathematical problems can be solved through computer simulation and numerical calculation.

In the development process of computational science and mathematics, the trend of integration between computational thinking and calculus is becoming increasingly evident. On the one hand, with the continuous development of computer science and technology, more and more mathematical problems and algorithms are transformed into computer programs for solving, which makes computational thinking occupy an increasingly important position in mathematical research and teaching. On the other hand, many concepts and theories in calculus are widely applied in the field of computer science, such as numerical analysis, algorithm design, data structures, etc., all of which rely on the support of calculus. This mutual integration not only promotes the common development of the two disciplines, but also provides new ideas and methods for interdisciplinary research.

There is a close and complex relationship between computational thinking and calculus. They promote and integrate with each other, jointly driving the development of fields such as technology, engineering, and mathematics. In the future development, we should continue to strengthen the crossover research between computational thinking and calculus, explore more new theories and methods to cope with more complex and ever-changing challenges and problems. At the same time, we should also focus on integrating computational thinking into calculus teaching, cultivating students' innovative thinking and practical abilities, and laying a solid foundation for their future development.

### 2.1 The course of calculus contains rich computational thinking

Studying calculus is not only a process of delving into the field of mathematics, but also an effective way to cultivate a series of important computational thinking abilities. In fields such as mathematics, physics, engineering, economics, and computer science, these computational thinking skills are of great significance for solving various problems.

Many concepts in calculus, such as limits, derivatives, integrals, etc., are abstracted from concrete problems. These concepts may not have direct counterparts in real life, but they can accurately describe and explain many natural phenomena and scientific problems. Therefore, the study of calculus requires students to have the ability of abstract thinking, be able to abstract mathematical models from specific practical problems, and then describe and solve them using mathematical language.

The theorems, formulas, and derivation processes in calculus all follow strict logical rules. For example, deriving the properties of derivatives through the definition of limits, and proving the integral formula using the fundamental theorems of calculus. Students need to gradually cultivate their logical thinking ability in the learning process, and learn to start from known conditions and draw conclusions through logical reasoning. This logical thinking ability helps cultivate students' rigorous thinking style and problem-solving skills.

Calculus emphasizes the quantitative analysis of problems, that is, transforming actual problems

into mathematical problems through the establishment of mathematical models, and then solving them using mathematical methods. This quantitative thinking requires students to have the ability to simplify complex problems into mathematical models, as well as the ability to accurately describe and solve problems in mathematical language. Quantitative thinking helps people to have a more objective and accurate understanding of the world and solve problems.

Many calculations in calculus rely on algorithms to complete, such as solving equations, integrals, series, etc. Algorithmic thinking requires students to be able to design efficient and accurate algorithms to solve mathematical problems. This algorithmic thinking is not only of great significance in mathematics learning, but also has extensive application value in fields such as computer science and engineering technology.

Reverse thinking plays an important role in calculus. It enables us to examine problems from another perspective and find new methods and ideas for solving them. For example, when solving certain types of integrals, we can use the partial integration method or the substitution integration method to transform them into simpler forms for solving; when solving differential equations, we can also find simpler solutions through reverse thinking. In addition, integration is the reverse operation of differentiation, which is also an important application of reverse thinking in calculus.

Calculus contains rich philosophical ideas, such as quantitative and qualitative changes, differentiation and integration, finite and infinite, etc. These philosophical ideas not only help people to have a deeper understanding of mathematical concepts and theorems, but also inspire their way of thinking and worldview. Philosophical thinking enables students to examine mathematical problems and social phenomena from a broader perspective, thereby cultivating their critical thinking and innovation abilities.

The computational thinking contained in calculus is multifaceted and profound. It requires students to possess various abilities such as abstract thinking, logical thinking, quantitative thinking, algorithmic thinking, reverse thinking, and philosophical thinking. The cultivation of these abilities not only helps students achieve excellent results in mathematics learning, but also provides important support for their future scientific research, engineering technology, and daily life.

## 2.2 The cultivation path of computational thinking in calculus

Calculus is an important platform for cultivating students' computational thinking. Computational thinking is an advanced thinking ability that emphasizes breaking down complex problems into manageable parts and solving them through logical analysis and algorithm design. In the study of calculus, a series of strategies and methods can effectively cultivate students' computational thinking ability.

Firstly, teachers can cultivate computational thinking by strengthening the theoretical foundation of calculus. On the one hand, it is important to have a deep understanding of the basic concepts and formulas of calculus. The concepts and formulas in calculus are the cornerstone of computational thinking. Students need to deepen their understanding and mastery of these basic concepts and formulas through extensive learning and practice, in order to be able to flexibly apply them in subsequent calculations and applications. On the other hand, mastering basic calculation skills and methods. The calculation skills and methods in calculus are the key to solving problems, and mastering basic calculation skills and methods can help students quickly find effective solutions when solving complex problems.

Secondly, teachers can cultivate computational thinking by strengthening students' logical thinking ability. Logical thinking is an important component of computational thinking. Students can exercise their logical thinking ability by solving logical reasoning problems, participating in math competitions or problem-solving challenges. Theorems and proof processes in calculus often involve

complex logical reasoning. By learning and applying these theorems and proof processes, students can further enhance their logical thinking abilities.

Thirdly, teachers can encourage students to think from multiple perspectives to cultivate computational thinking. Teachers should encourage students to try to find the optimal solution from different perspectives and ideas during the calculation process. This helps cultivate students' innovative thinking and flexible application abilities. By transforming their thinking, students can turn complex problems into simple ones, making it easier to find solutions. For example, when solving calculus problems, complex problems can be simplified through methods such as variable substitution and partial integration.

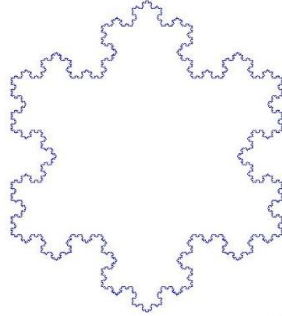


Figure 1: Koch snowflakes with limited area and infinite circumference

Fourthly, teachers can introduce mathematical experiments into calculus courses. By participating in mathematical experiments, students can apply their learned knowledge to practical problems, which helps cultivate their practical and problem-solving abilities. Students can use mathematical software such as MATLAB for calculations and analysis, which have powerful computational functions and visualization tools that can help them better understand and apply mathematical knowledge. For example, when explaining series, the magical and beautiful Koch snowflakes can be introduced, as shown in Figure 1.

Fifthly, teachers can cultivate computational thinking by introducing mathematical experiments into calculus courses. By participating in mathematical experiments, students can apply their learned knowledge to practical problems, which helps cultivate their practical and problem-solving abilities. Students use mathematical software such as MATLAB for calculations and analysis, which have powerful calculation functions and visualization tools that can help students better understand and apply mathematical knowledge. For example, approximate the square wave function by using Fourier series, as shown in Figure 2.

$$f(x) = \frac{4}{\pi} \left[ \sin x + \frac{1}{3} \sin 3x + \dots + \frac{1}{2k-1} \sin(2k-1)x + \dots \right]$$

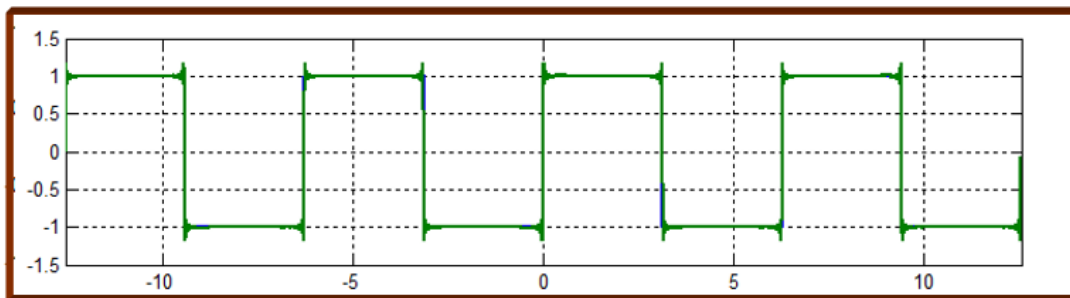


Figure 2: Approximate the square wave function by using Fourier series

Sixthly, through case-based teaching and problem oriented teaching, students are guided to actively think, explore, and solve practical problems, encouraged to put forward their own opinions and solutions, cultivate their abstract thinking and modeling abilities, as well as critical thinking and innovation abilities.

In summary, cultivating computational thinking in calculus requires multiple efforts and practices. Through the above methods, students' computational thinking can be effectively cultivated in calculus courses, helping them better understand the basic knowledge of calculus and improve the effectiveness of computational thinking training.

### 3. Conclusions and Discussion

Cultivating computational thinking in calculus courses has profound significance. It can not only enhance students' problem-solving ability and innovative thinking, but also strengthen their interdisciplinary application ability and rigorous mathematical literacy. At the same time, the cultivation of this kind of thinking also helps promote students' personal growth and development, laying a solid foundation for their future career.

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