

Some Thoughts on the Connection Between Middle School Mathematics and College Mathematics Courses

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Abstract:

The issue of learning transition is a challenge every freshman faces when entering higher education institutions. For freshmen at the Sino-European Institute of Aviation Engineering, Civil Aviation University of China, transitioning from high school mathematics to advanced mathematics is the primary concern upon entering university. This paper examines how to effectively bridge the gap between high school mathematics and advanced mathematics from the perspective of higher education.

Keywords:

Learning Situation, Teaching Content, Teaching Strategy, After-class Support

1. Introduction

The importance of the connection between high school mathematics and advanced mathematics is mainly reflected in the following aspects: (1). Knowledge Continuity: High school mathematics serves as the foundation for advanced mathematics, which further deepens and expands on high school content. Only with a good connection can students make a smooth transition. Conceptual Continuation: Concepts such as functions, limits, and derivatives are initially introduced in high school and further developed in advanced mathematics. Poor connections can lead to difficulties in understanding. (2). Cognitive Shift: From Concrete to Abstract: high school mathematics focuses on specific calculations, while advanced mathematics emphasizes abstract thinking and logical reasoning. A good connection helps students adapt to this shift. From Intuitive to Rigorous: high school mathematics relies on intuitive understanding, whereas advanced mathematics requires rigorous proofs and derivations. A good connection helps students gradually adapt. (3). Learning Efficiency: Good connections can avoid redundant learning and improve efficiency. Reducing Difficulty: Proper connections help students gradually adapt to the complexity of advanced mathematics, reducing their academic pressure. (4). Teaching Optimization: Course Design: Connections help optimize course design, ensuring content coherence. Teaching Methods: Teachers can adjust teaching methods based

on the connection, helping students transition smoothly. Therefore, the connection between high school mathematics and advanced mathematics is crucial in terms of knowledge continuity, cognitive shift, learning efficiency, application ability, psychological preparation, and teaching optimization, directly impacting students' learning outcomes and future development.

From the perspective of advanced mathematics teaching, this paper studies how to help students smoothly connect high school mathematics and advanced mathematics. To this end, the author believes that we should start from the following aspects.

2. Study the Learning Situation Thoroughly

The study of students' learning situation is the basic element of advanced mathematics teaching. In view of the differences in the content of high school mathematics teaching in different provinces in China and the characteristics of the cultivation mode of excellent engineers, the author conducted the following small-scale study on the learning situation to understand whether there are differences in the mastery of mathematical content among students from different provinces and cities:

Firstly, Chongqing students have not been exposed to predicate logic, making it difficult for them to fully understand and easily confuse the order of existence and universality, see Figure 1. The order of universal quantifiers and existential quantifiers can alter the essential meaning of mathematical descriptions: if the universal quantifier comes first, the description only represents the property of the propositional variable itself; if the existential quantifier precedes, it indicates the overall property of the propositional object. For example, the definition of "boundedness" for a function should be expressed with an existential quantifier before the universal quantifier; otherwise, it would only indicate that each function value can be surpassed. In teaching, students often make incorrect expressions, so understanding and mastering this concept is crucial for subsequent mathematics knowledge, such as mathematical analysis and advanced algebra. This should be given full attention in the teaching process, with reasonable adjustments to teaching strategies and course implementation plans.

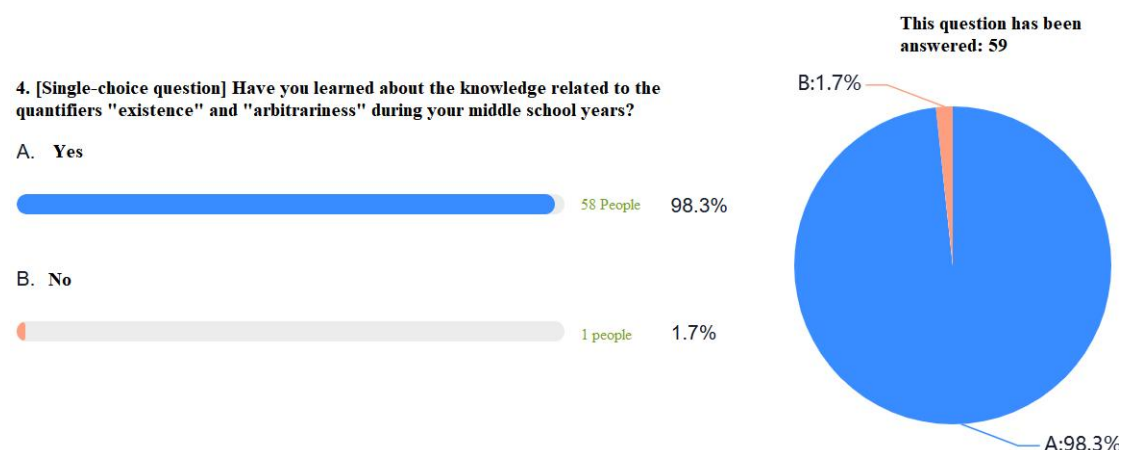


Figure 1. Questionnaire on Quantifier.

Secondly, the logical basis commonly used in mathematical proofs: Syllogism, the logically equivalence of the original proposition and its contrapositive (i.e., contraposition), as well as common proof methods in mathematics: reductio ad absurdum and mathematical induction, see Figure 2, in some provinces and cities

during middle school, classroom content has touched on these topics, but there has been no systematic introduction to logical principles and their correct application. Students mostly use them based on intuition, failing to clearly understand the context and proper steps, leading to an incomplete logical thinking process.

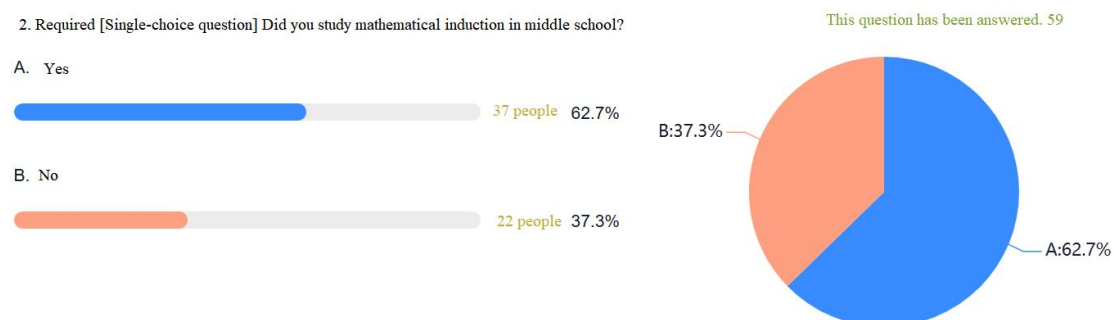


Figure 2. Questionnaire on mathematical induction.

Thirdly, complex numbers. Although complex numbers have been introduced in high school education across almost all provinces, students only understand the basic operations of complex numbers and are not familiar with the mathematical background and origin of pure imaginary numbers i . They also cannot write them correctly, often making mistakes like taking the square root of negative numbers. Additionally, they have not learned about complex exponents or n -th roots of unity. This content should be included in the first semester.

Fourthly, the understanding of derivative content varies greatly among students from different provinces. For instance, candidates in Shanghai have never been exposed to the concept of derivatives, whereas those from Hebei, Shandong, Hubei, Jiangsu, and Anhui provinces not only learn the formulas for calculating derivatives but also understand the application of L'Hôpital's Rule, see Figure 3. These differences in knowledge base should be fully considered in teaching.

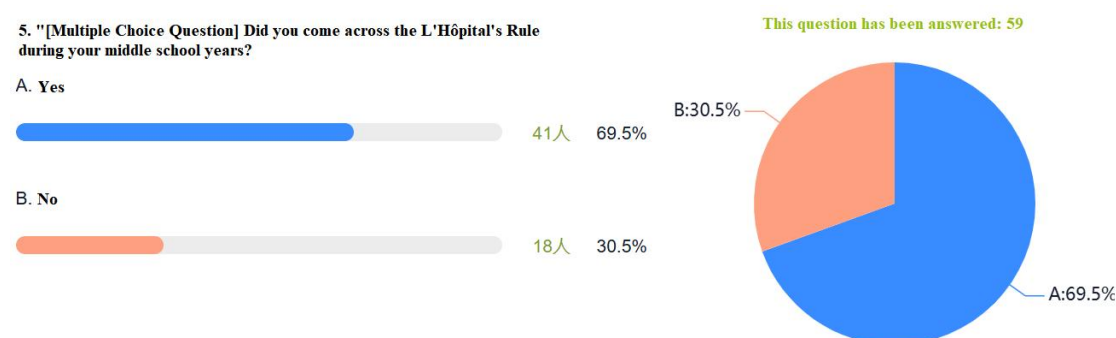


Figure 3. Questionnaire on L'Hôpital's Rule.

3. Arrange Teaching Content Reasonably

In view of the significant differences in students' middle school foundation, the teaching content should be formulated to take into account the integrity of the subject system, students' cognitive laws and the difference of knowledge basis.

First, in terms of content setup, at the beginning of the course, basic knowledge of mathematical logic is introduced. This includes the logical foundation required for mathematical proofs and commonly used proof methods, as well as universal quantifiers, existential quantifiers, and the negation of propositions. In other words, predicate logic and related content should be covered upfront. These topics are taught

in the first chapter of the course. On one hand, this helps students review and summarize the logical foundations they have learned in high school while reinforcing their understanding. On the other hand, it provides necessary logical support for subsequent mathematics courses, especially laying a solid foundation for learning mathematical proofs. For example, only by understanding predicate logic can students grasp the true meaning of mathematical definitions related to limits; knowing the logical underpinnings of mathematical proof methods aids students in comprehending the essence of mathematical proofs and helps them quickly master these methods. Common logical bases used in mathematical proofs include syllogistic proofs, the equivalence of the original proposition and its contrapositive (i.e., mathematical induction), and common proof methods such as *reductio ad absurdum* and mathematical induction. Teaching these before teaching mathematical analysis allows students to understand the logical underpinnings of proof methods like *reductio ad absurdum*. This ensures that students clearly understand the logical basis of mathematical proofs in their subsequent studies and recognize the correct thinking process in mathematical proofs. It also helps students form strong logical thinking skills when studying mathematical analysis, laying a solid foundation for developing a deep mathematical and logical base.

Secondly, appropriately supplement the theoretical background of mathematics to help students with different foundational backgrounds grasp relevant knowledge points from their roots. For example, regarding complex numbers, all students know that the pure imaginary number i is the square root of -1 , but the function of taking square roots has a domain that is only positive real numbers. Therefore, this definition can be somewhat ambiguous. In this course, the teaching content approaches the mathematical background of i from the perspective of Cartesian Product and systematically covers topics such as complex exponents, laying a solid foundation for subsequent Fourier analysis and physics studies.

Finally, considering the instrumental nature of mathematics courses, adding chapters on the definition and derivatives of basic elementary functions not only provides a research subject for subsequent mathematics studies but also lays the foundation for solving differential equations in physics. Introducing the properties of derivative calculations for basic elementary functions in the first semester of university can both address the lack of exposure to derivatives among some students (for example, Shanghai candidates in 2022 had no prior contact with concepts related to function differentiation during their middle school years) and systematically guide students through learning and practicing the calculation of derivatives for common functions, mastering the basic techniques and commonly used rules for derivative calculations.

In summary, in the first semester of advanced mathematics instruction, it is essential to consider the varying levels of students' foundational knowledge while emphasizing the novelty and completeness of the content. This approach helps prevent students from overlooking important aspects during the teaching process. It facilitates a smoother transition into university-level mathematics learning.

4. Reasonable Formulation of Classroom Teaching Strategies

On the basis of sufficient study of students' learning situation, it is the first task to formulate teaching strategies that take into account fairness, efficiency and individuality in view of the differentiated phenomenon of students' knowledge base.

First, differentiated content design. Adopt the core + extension mode: all students master the core knowledge points (such as the definition of interval), and students with good foundation learn additional expansion content (such as using the ε -language to prove interval problems, dense subset proof of real numbers).

Second, step-by-step examples. Different solutions are set for the same problem (such as the sum of trigonometric functions, and the calculation related to the n -th unit root of complex numbers).

Third, interactive and collaborative learning. Mixed grouping: students with different basic skills are grouped together to complete tasks (such as chapter assignments) through cooperation, encouraging cooperation and communication among classmates and promoting mutual assistance.

Fourth, the "little teacher" mechanism: students with good foundation assist in explaining, consolidate their own knowledge and help others.

Fifth, multimodal teaching. Use visualization tools: use geometric intuition (such as function image animation) to help students with weak foundation understand abstract concepts.

Sixth, life case: combining the equation of catenary to explain hyperbolic function and trigonometric function can help students understand by analogy.

5. After-class Support System

First, flexible assignments and feedback. Assignments are divided into required (chapter exercises and chapter homework problems) and optional (thinking questions), allowing for self-selection of difficulty. Personalized comments: In grading chapter homework, provide feedback on the root cause of errors (such as "Your problem lies in not considering the additional roots generated by the transformation when solving inverse trigonometric equations").

Secondly, supplementary resources and tutoring. Provide tiered learning materials: such as basic review videos and advanced reference book selections. Ensure effective Q&A sessions, allowing students to add personal social media accounts for online Q&A at any time. Address common issues through concentrated explanations: organized by theme based on needs (such as "Consolidation Class for Summation of Trigonometric Functions").

Finally, technical tools to assist. Adaptive learning platform: recommend personalized exercises (such as extended reading of math reference books). Online discussion area: encourage students to ask questions anonymously to reduce psychological pressure.

6. Conclusions

This article primarily explores the issue of ensuring a smooth transition from high school mathematics to university mathematics education in an international cooperative program. It first analyzes the current learning situation, then provides

reasonable teaching content, and enhances classroom teaching quality and effectiveness through appropriate teaching strategies and after-class support systems. This research offers insights for contemporary advanced mathematics instruction but leaves room for further exploration in terms of model promotion.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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