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AI-Enabled Difference Analysis and Bridging Transformation Between High School Mathematics and Advanced Mathematics

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Abstract: The difficulty of bridging high school mathematics and advanced mathematics has long plagued first-year university students. Its causes are mainly threefold: at the knowledge level, there is both repetition and discontinuity; at the thinking level, the leap from "concrete computation" to "abstract argumentation" proves arduous; and at the learning level, the shift from "teacher-led guidance" to "self-directed construction" causes considerable discomfort. The introduction of AI technology has opened up new possibilities for resolving this dilemma: intelligent diagnosis can precisely identify students' knowledge gaps and cognitive biases, personalized recommendation engines can dynamically plan bridging solutions according to students' varying foundations, and knowledge graphs can help build a cognitive ladder from elementary mathematics to advanced mathematics. Based on an analysis of the essential differences between the two stages of mathematics in three dimensions—knowledge system, logical thinking, and learning approach—this paper explores the internal mechanisms and implementation pathways of AI-enabled bridging transformation, with the aim of providing reference for the teaching reform of advanced mathematics courses.

1. Introduction

Advanced mathematics, a core public foundational course at the university level, is also the subject in which first-year students face the most prominent learning adaptation difficulties. Many students feel overwhelmed from the very first class, and since advanced mathematics knowledge is closely interconnected, an early misunderstanding can easily cascade into setbacks in subsequent learning. The underlying cause lies not in the intrinsic difficulty of advanced mathematics itself, but in the pronounced "cognitive disconnect" and "transitional gap" between high school and university mathematics education.

Existing research has identified the structural causes: topics such as derivatives, functions, and limits are covered at both stages, yet university-level exploration remains limited, resulting in an inefficient transition of "much repetition but little deepening[1-2]." Meanwhile, content such as

inverse trigonometric functions and polar coordinate transformations has been removed from the high school curriculum, only to become essential at the university level, creating a rupture in the knowledge chain. More critically, students generally struggle with the cognitive shift from "intuitive computation" to "formal proof." Concurrently, AI technology's accelerating penetration into education has created new opportunities for resolving these challenges[3]. Intelligent diagnosis can accurately identify knowledge blind spots, personalized recommendations can design differentiated pathways for students with different starting points, and knowledge graphs can connect scattered knowledge points into a navigable cognitive network[4-5].

This paper aims to systematically examine the essential differences between advanced mathematics and high school mathematics across three dimensions—knowledge system, logical thinking, and learning approach—and on this basis, explore concrete pathways for achieving a smooth transition and competency advancement under AI empowerment. Specifically, it will first analyze core differences between the two stages in content organization, cognitive requirements, and learning modes. It will then examine mechanisms through which AI-powered intelligent diagnosis, personalized recommendation, and knowledge graphs facilitate bridging and transformation. Finally, drawing on teaching practice, it will propose actionable bridging strategies to provide both theoretical reference and practical guidance for the teaching reform of advanced mathematics courses.

2. Essential Differences Between Advanced Mathematics and High School Mathematics

2.1. Knowledge System: From "Finite and Concrete" to "Infinite and Abstract"

The knowledge system of high school mathematics is structured around elementary functions, with content largely centered on finite values and finite operations. Although the concept of functions is introduced, understanding remains primarily at the intuitive level of "correspondence." Limits appear only as introductory material, and the teaching of derivatives emphasizes computation and simple applications. In contrast, university-level advanced mathematics takes "limits" as its logical starting point, achieving a leap from finite to infinite, from discrete to continuous, and from concrete operations to abstract structures.

The direct consequence of this leap is the simultaneous presence of knowledge repetition and knowledge disconnection. Taking derivatives as an example, high school has already covered the definition of derivatives, differentiation rules, and their geometric meaning. These topics reappear at the university level, but the teaching focus shifts to the rigorous formulation of limit definitions, the proof of the relationship between differentiability and continuity, and the systematic construction of the mean value theorem. If teachers merely repeat what was taught in high school, students will struggle to perceive what is "new"; if teachers move directly into abstract argumentation, students who have not yet developed the habit of elementary mathematical thinking will find it abrupt and disorienting.

2.2. Logical Thinking: From "Mechanical Application" to "Logical Argumentation"

The divergence in thinking modes constitutes the most fundamental difference between the two stages of mathematics. The learning approach in high school mathematics tends to emphasize "applying specific formulas and solving problems according to fixed question-type routines." Problems typically provide explicit numerical conditions, and students need only substitute data into ready-made formulas to obtain answers. Over time, students develop an assembly-line mentality of "identify the question type—match the method—calculate the result."

Advanced mathematics, by contrast, demands an entirely different quality of thinking. It takes

the change of variables and logical derivation as its main thread, shifting from static numerical computation to dynamic analysis of patterns, with attention to the origins and development of theorems, their conditions of applicability, and their logical interconnections. A limit problem may involve no concrete numerical calculation at all, but instead set analytical traps around the conditions for the existence of limits and the concepts of infinitesimals and infinities. A proof problem may require students to start from definitions and demonstrate the equivalence between differentiability and derivability. If students continue to follow the high school habit of "seeking only the answer," they will find themselves at a loss when confronted with conceptual analysis and proof-based problems. Some studies characterize this shift as a cognitive breakthrough "from intuitive computation to formal proof," noting that this process requires the aid of geometric intuitive tools.

2.3. Learning Approach: From "Follow-the-Teacher" to "Self-Directed Construction"

The learning environment in high school mathematics is highly structured: progress is uniformly controlled by the teacher, assignments are uniformly distributed, tests are conducted at regular intervals, and students need only follow the teacher's pace. Learning outcomes are measured primarily through standardized examinations, with feedback being timely and clearly directed.

University-level advanced mathematics, by contrast, presents a different learning ecology: large-class instruction, a markedly accelerated pace, and limited opportunities for individualized tutoring, making self-learning ability a key factor affecting academic performance. The density of course content is high, and the amount of information conveyed in classroom lectures far exceeds that of high school, requiring students to invest substantial time after class in digestion, consolidation, and practice. More importantly, university mathematics emphasizes the presentation of "the analytical process of knowledge," aiming to inspire and cultivate students' mathematical literacy and competence rather than merely imparting problem-solving techniques.

3. Core Mechanisms of AI-Enabled Bridging Transformation

3.1. Intelligent Diagnosis: Precisely Identifying Knowledge Gaps and Cognitive Biases

The crux of the transition difficulty often lies not in "new knowledge being too abstruse," but in "old knowledge not being firmly grasped." After the college entrance examination, many students have only a vague memory of inverse functions, composite functions, piecewise functions, and the graphs and properties of basic elementary functions—yet these very topics constitute the necessary prerequisites for understanding concepts such as limits and derivatives in advanced mathematics.

This is precisely where the value of an AI-powered intelligent diagnostic system lies: it can accurately pinpoint knowledge gaps before or at the very beginning of students' formal study of advanced mathematics through adaptive testing. Unlike traditional "one-size-fits-all" placement exams, an AI system dynamically adjusts question difficulty and knowledge coverage based on students' performance, thereby generating a personalized "knowledge weakness profile." For students with an unclear understanding of function concepts, the system prioritizes review modules on the graphs and properties of elementary functions. For those lacking intuitive understanding of limits, it provides visual demonstrations of the changing process of sequence limits. Through this mechanism, transitional teaching can shift from "uniform review" to "targeted remediation."

3.2. Personalized Recommendation: Differentiated Pathways for Varying Foundations

The complexity of the transition problem lies in the uneven starting points of students. Some

students have a relatively solid foundation in high school derivatives and need to make the cognitive leap toward the rigorous definition of limits; others struggle even with basic function operations and urgently require systematic knowledge reconstruction. Faced with such significant individual differences, traditional teaching models can hardly accommodate all students' needs simultaneously.

An AI-powered personalized recommendation engine, however, can integrate students' diagnostic results, learning behavior data, and disciplinary requirements to tailor differentiated transition pathways for each individual. For students with weak foundations, the system guides them to begin with a review of core elementary knowledge and gradually transition to introductory concepts in advanced mathematics. For those with solid foundations, the system leads them directly into comparative inquiry between "high school knowledge and university perspectives"—for example, extending from the "geometric meaning of derivatives" at the high school level to the "essential nature of linear approximation in differentials" at the university level—thereby achieving cognitive deepening rather than simple repetition.

3.3. Knowledge Graph: Bridging Elementary and Advanced Mathematics Cognitively

Knowledge graph technology offers an effective means of resolving the problem of "knowledge fragmentation." The knowledge points of high school and advanced mathematics are not isolated from each other but share deep logical connections: the "infinite approach" in high school sequences can be seen as an intuitive precursor to the university concept of limits; the high school understanding of derivatives as "instantaneous rates of change" constitutes the cognitive starting point for the rigorous definition of derivatives at the university level; and the "graph transformations" of high school functions provide visual support for analyzing function properties in advanced mathematics.

With AI-driven knowledge graphs, these connections can be presented visually, helping students build cognitive bridges between the "known" and the "unknown." When students encounter the ε-δ definition of limits, the system can simultaneously display its correspondence with high school descriptions of sequence limits. When students learn the concept of differentials, the system traces back to the geometric meaning of derivatives in high school and presents the cognitive extension from "tangent slope" to "linear principal part." This approach of "connecting past and present, contrasting old and new" helps reduce the difficulty of understanding abstract concepts.

4. Core Mechanisms of AI-Enabled Bridging Transformation

4.1. Pre-Enrolment: Intelligent Preparatory Learning and Cognitive Readiness

Relying on an AI learning platform, a "precision bridging" preparatory course can be offered during the summer vacation or before the semester begins. Unlike traditional "pre-learning advanced mathematics," AI-enabled preparatory learning follows a three-step approach: "filling gaps—bridging—introduction." In the first step, the system diagnoses and fills knowledge gaps from high school, focusing on high-frequency foundational content used in university mathematics, such as functions, sequences, inequalities, and logical terminology. In the second step, through a comparative approach of "high school knowledge versus university perspectives," students are helped to perceive the shift in thinking modes. In the third step, intuitive understanding of core concepts in advanced mathematics—such as limits, derivatives, and differentials—is appropriately introduced to alleviate anxiety in the introductory stage.

4.2 In-Class Teaching: From "Repetitive Instruction" to "Cognitive Leap"

When addressing knowledge points that overlap with high school content, instructors of advanced mathematics should deliberately incorporate a "cognitive comparison" segment. Taking derivative instruction as an example, students can be guided to consider: How was the derivative understood in high school? Why does university-level study require redefining it? What problems that the original understanding could not address does the new definition resolve? This "review—deepen—extend" instructional arrangement helps students achieve a transition from "being able to compute" to "understanding the rationale."

4.3 After-Class: Personalized Remediation and Cognitive Training

The after-class stage is a critical phase for bridging and transformation. Based on classroom assessment data, the AI learning platform can push targeted practice content to each student: for those whose conceptual understanding remains incomplete, it provides definition discrimination and concept comparison exercises; for those with weaker computational skills, it offers tiered and progressive computational training; and for those whose thinking has not yet completed the leap, it provides comparative analysis of "high school problems versus university problems," guiding students to perceive the differences between the two modes of thinking.

5. Conclusions

The transition challenge between high school and advanced mathematics is, in essence, an adaptation problem triggered by a "structural leap" in students' cognitive development. Knowledge repetition and disconnection are merely external manifestations; the deeper challenge lies in the threefold transformation of thinking modes: from concrete to abstract, from computation to argumentation, and from teacher-dependent to self-directed. The significance of AI technology lies not in replacing the teacher's guiding role, but in providing more precise diagnosis, more personalized support, and more intuitive cognitive tools for this transformation. When intelligent diagnosis can accurately locate each student's "cognitive starting point," when personalized recommendations can chart differentiated pathways for students with varying foundations, and when knowledge graphs can link old and new knowledge into a navigable cognitive map, bridging transformation ceases to be a vague process of "students figuring it out on their own" and becomes a teachable, intervenable, and assessable component of instruction. This may well be the most pragmatic and transformative focus of AI-enabled advanced mathematics teaching.

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