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Analysis of the Penetration Strategy of Mathematical Culture in Elementary School Mathematics Classroom Teaching under Core Literacy

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Abstract: This study focuses on the infiltration path of mathematical culture in primary mathematics classrooms under the perspective of core literacy, and explores the synergy mechanism between disciplinary nurturing value and cultural inheritance. Aiming at the current phenomenon of cultural fragmentation in primary mathematics education, the study combines classroom observation and teaching case study to reveal the real dilemmas of teachers' cultural cognitive bias, lagging methodological innovation, insufficient development of resources, and single evaluation orientation. Based on the deep coupling of the three-dimensional objectives of core literacy and the connotation of mathematical culture, the study proposes systematic strategies such as reconfiguring the teaching design with cultural infiltration, revitalizing the classroom form with diversified interactions, broadening the penetration carriers with resource integration, and optimizing the cultivation of literacy with assessment and training linkage. The study breaks through the traditional technical teaching improvement ideas, constructs a new paradigm of mathematics education from the cultural and philosophical level, provides both theoretical value and practical significance for the implementation of the fundamental task of cultivating moral integrity, and helps the symbiotic development of students' quality of mathematical thinking and their sense of cultural identity.

Keywords: Core Literacy; Elementary School Mathematics; Mathematical Culture; Penetration Strategy

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1.Introduction

Mathematics education is undergoing a paradigm shift from knowledge-based to literacy-based, and the penetration of mathematical culture under the guidance of core literacy has become a key entry point for deepening curriculum reform. As a basic subject that lays the foundation of thinking, primary mathematics carries the dual mission of spreading the spirit of reason and passing on human civilization, but the dilemma of losing cultural connotation is common in actual teaching. Teachers pay too much attention to problem-solving skills training, ignoring the history of mathematics, mathematical beauty and mathematical application of the value of mining, resulting in the classroom into a symbolic drill. This kind of instrumental rationality orientation cuts off the connection between mathematical knowledge and its cultural parent body, and weakens the realization of the discipline's nurturing function [1]. This study is based on the intrinsic connection between core literacy and mathematical culture, analyzes the blocking factors of the integration of the two, and explores the practical path of cultural penetration, aiming at awakening the cultural self-awareness of the mathematics classroom, enabling students to

grasp knowledge and skills while comprehending the evolution of mathematical thinking, cultivating the scientific spirit and cultural comprehension, and realizing the development of mathematical education from the "material layer" to the "cultural layer". The aim is to awaken students' cultural consciousness in the math classroom so that they can master knowledge and skills, understand the evolution of mathematical ideas, cultivate scientific spirit and cultural understanding, and realize the qualitative leap of math education from the "object layer" to the "cultural layer".

2.The relationship between core literacy and mathematical culture

Core literacy and mathematical culture show a close inter-constructive relationship in primary mathematics education. While core literacy emphasizes students' key abilities and character for lifelong development, mathematical culture covers multiple dimensions such as mathematical thinking and methods, historical development, and social application, both of which point to the deep value of mathematics education. As a carrier for the cultivation of core literacy, mathematical culture helps students go beyond mere skill training to form rational thinking and innovative consciousness by revealing the logical system and humanistic connotation behind mathematical knowledge. For example, the exploration of classical problems in the history of mathematics can guide students to experience the process of knowledge formation and cultivate their critical thinking ability; the connection between mathematics and real life inspires students to use models to solve practical problems. At the same time, the core literacy framework provides a clear direction for the penetration of mathematical culture, prompting teachers to shift from the mere transmission of knowledge to cultural infiltration, and to incorporate the beauty of ideas and logic behind mathematical symbols into the design of teaching and learning. This two-way interactive relationship requires educators to explore the resources of mathematical culture in depth, but also need to accurately dock the core literacy goals, and build a symbiotic path between cognitive development and cultural experience in classroom practice.

3.Problems of mathematical culture penetration in elementary school mathematics classroom teaching under core literacy

3.1 Teachers' insufficient knowledge of mathematical culture

In the core literacy-oriented elementary mathematics classroom, teachers' insufficient knowledge of mathematical culture has become a key bottleneck restricting cultural penetration. Some teachers' understanding of mathematical culture is limited to fragments of mathematical history or interesting stories, and they lack a systematic grasp of its philosophical implications, thinking paradigms and social values. Influenced by the test-taking mindset for a long time, teachers tend to simplify mathematics into formula derivation and problem training, ignoring the logical evolution and cultural accumulation behind the formation of mathematical concepts. This cognitive bias makes it difficult to break through the framework of instrumental knowledge transfer in teaching design, for example, the teaching of pi only emphasizes on numerical memorization and cuts off the subtle process of human exploration of infinity behind it, and the solving of quadratic equations stays in step-by-step exercises but shields the revolution of abstract thinking carried by algebraic symbols. The deeper problem lies in the fact that teachers' own weak cultural reserves limit the depth of the classroom, and they are unable to guide students to appreciate the axiomatic system of mathematics and the beauty of its artistic structure. Although some teachers are aware of the importance of cultural penetration, they are limited by their lack of cross-disciplinary vision, making it difficult for them to transform the cultural links between mathematics and architecture, music and other fields into teaching resources [2].

3.2 Lack of vitality of single teaching method

The monotony of teaching methods in the current elementary mathematics classroom has significantly weakened the effectiveness of the penetration of mathematical culture. Teachers are accustomed to the linear model of lecture and practice, and overly rely on the mechanical reproduction of example problems from the textbook, resulting in the classroom being reduced to a programmed rehearsal of problem-solving steps. Taking the unit of "Preliminary Understanding of Fractions" as an example, most teachers only explain the concept of equivalent fractions by cutting physical models, but fail to guide students to trace the civilized wisdom of the ancient Egyptian unit fraction notation, or compare the differences between the Chinese and Western ancient fractions systems, thus missing the opportunity to deepen their mathematical understanding through cultural comparisons. Teacher-student interactions in the teaching process are mostly confined to question-and-

answer knowledge confirmation, and there is a lack of multi-approaches such as project inquiry and dramatic situation reconstruction, which makes it difficult to transform the conflicts and breakthroughs in the history of mathematics into tangible learning experiences. This solidified model suppresses the cultural generativity of the classroom, students passively accept the conclusions and cannot experience the process of knowledge re-creation, and the innovative consciousness and cultural understanding required by the core literacy are reduced to paper concepts. The lack of vitality in teaching methodology reflects the teachers' weak knowledge of cultural transformation ability, and it is urgent to build an open and diversified teaching form to activate the educational potential of mathematical culture.

3.3 Insufficient utilization of teaching resources

The depth of mathematical culture penetration in primary mathematics classrooms is limited by the superficiality of teaching resources development. Teachers generally regard textbook illustrations and after-school reading materials as the main body of cultural resources, and fail to systematically explore the potential value of mathematics history, interdisciplinary practice cases and digital resources. Take the teaching of "symmetrical figures" as an example, most classrooms only present standard geometric figures, but ignore the aesthetics of mirror symmetry in Dunhuang murals or the wisdom of topological transformations in the patterns of window panes in Suzhou gardens, leaving the cultural elements at the level of conceptual illustration. The selection of teaching resources is often separated from historical contexts and real-life applications. For example, the teaching of probability seldom introduces the primitive statistical thinking of oracle bone divination, and the unit on weights and measures seldom compares the social motivations for the evolution of ancient and modern units of measurement. A more prominent problem is that the integration of resources lacks regional cultural appropriateness, and the tenon and mortise structure of local traditional architecture and the logic of operation and research contained in folk games are not transformed into teaching carriers. The singularity and flattening of the use of resources not only weaken the infectious power of mathematical culture, but also lead to the cultivation of core literacy into an abstract sermon divorced from the cultural context.

3.4 Imperfect and unscientific evaluation system

The imperfection of the current evaluation system seriously restricts the organic penetration of mathematical culture in elementary school classrooms. The assessment mechanism dominated by score evaluation focuses excessively on calculation accuracy and problem solving speed, and neglects the examination of students' mathematical aesthetic experience, cultural comprehension and other dimensions of literacy. For example, the teaching evaluation of the "chicken and rabbit in the same cage" problem often stops at determining the correctness of the algebraic solution, and fails to design an assessment tool for observing students' cultural transfer ability to reconstruct the problem by using the original ideas of Sun Tzu's Mathematical Scriptures. The evaluation method mostly adopts standardized tests, and lacks the development of process evaluation carriers such as file bag records and cultural theme inquiry reports, which makes the key links in the formation of mathematical ideas, such as the verification of conjectures and cultural comparisons, a blind spot in the teaching and learning process. There is a structural disconnect between the evaluation content and the core literacy objectives. The unit on three-dimensional geometry rarely focuses on students' ability to interpret the cultural expression of the equations of the curved surfaces of the domes of Gothic buildings, and the teaching of statistical charts rarely examines students' data literacy in interpreting the patterns of the color distribution of Dunhuang murals [3].

4.The Infiltration Strategy of Mathematical Culture in Primary Mathematics Classroom Teaching under Core Literacy

4.1 Optimizing Teaching Design to Integrate Cultural Literacy

Optimizing teaching design requires integrating mathematical culture into the knowledge construction process and designing cultural experience activities that meet children's cognitive characteristics. When recognizing shapes, traditional architectural elements can be introduced, for example, the block model of the Forbidden City's corner tower can be used to help students understand the stability of triangles, and the charm of three-dimensional geometry can be felt by building arch structures. Numbers can be taught by combining ancient counting methods, making oracle bone number cards, and allowing students to understand the evolution of decimal counting in deciphering Shang Dynasty field and hunting divination. The concept

of fractions can be introduced with the help of traditional festivals and cultures, such as the activity of distributing rice dumplings in the Dragon Boat Festival, so that students can experience the meaning of fractions in the actual distribution. Classroom can be set up "mathematical culture corner", display abacus, sundials and other instruments, carry out "ancient shopping" role-playing, with the Kaiyuan Tongbao model of addition and subtraction operations, so that the history of monetary development and arithmetic skills training organic integration. Teaching design can be integrated into folk games, for example, upgrading the tangram board into the "Song and Yuan cargo ship assembly" task, students in the recovery of ancient sailing ship structure, naturally mastered the law of transformation of plane shapes. Mathematical elements in traditional arts should be explored, for example, analyzing the use of axisymmetric shapes in folk art in conjunction with paper-cutting activities, and using geometric color separation boards to design traditional tattoos. The application of digital tools should be in line with children's cognitive characteristics. An interactive program is developed to simulate the ancient time-keeping system, so that students can intuitively understand the cultural origin of the concept of fractions and time measurement when adjusting the relationship between the speed of water flow and the scale. This kind of instructional design emphasizes the connection between life experiences and cultural wisdom. For example, mathematical problems can be contextualized by designing the task of "management of ancient grain silos", so that students can understand the historical evolution of the unit of volume when calculating grain reserves [4].

4.2 Innovative Teaching Methods Activate Cultural Classroom

Innovations in teaching methods should focus on transforming mathematical culture into tangible activities perceivable by children. In recognizing numbers, a game of matching oracle bone numerical cards can be designed so that students can naturally understand the evolution of decimal counting when deciphering the quantity symbols in Shang Dynasty field and hunting divination. The creation of illustrated math books can lower the threshold of cultural cognition. For example, the bamboo folding problem in the Nine Chapters of the Mathematical Art of Arithmetic can be adapted into a story about a bear measuring the height of bamboo joints, and the principle of similar triangles can be demonstrated with the help of a three-dimensional flip book. Traditional festivals in the mathematical elements worth tapping, Dragon Boat Festival dumplings can be introduced into the "knot counting" practice, so that students in the bundling of reeds to observe the number of knots and three-dimensional geometry of the relationship between stability. Classroom can set up cultural experience corner, display abacus, sundial and other instruments, carry out "ancient shopping" role-playing, with the Kaiyuan Tongbao model for addition and subtraction operations, so that the history of monetary development and arithmetic skills training organic integration. Interdisciplinary project-based learning is of a practical nature. For example, students are guided to analyze the application of axisymmetric shapes in folk art in conjunction with the Chinese New Year window cuttings activity, and to use geometric color separation boards to design traditional patterns independently. The application of digital tools should be in line with children's cognitive characteristics, and the development of an interactive program to simulate the ancient leakage timekeeping, students can intuitively experience the cultural origin of the concept of fractions and time measurement when adjusting the relationship between the speed of water flow and the scale. This kind of pedagogical innovation emphasizes the connection between life experience and cultural wisdom. For example, by upgrading the jigsaw puzzle to the "Song and Yuan Cargo Ship Puzzle" task, students can subconsciously grasp the law of transformation of planar shapes when restoring the structure of ancient sailing ships. When mathematical knowledge is presented through the cultural vehicle of storytelling and gamification, abstract formulas and theorems are transformed into palpable cultural heritage. For example, the game of digital scales restores the idea of equations in Sun Tzu's Book of Arithmetic, and allows students to construct the concept of equations through the experience of weighing grains.

4.3 Integrating teaching resources to build a bridge of penetration

Optimizing teaching design requires integrating mathematical culture into the knowledge construction process and designing cultural experience activities that meet children's cognitive characteristics. When recognizing shapes, traditional architectural elements can be introduced, for example, the block model of the Forbidden City's corner tower can be used to help students understand the stability of triangles, and the charm of three-dimensional geometry can be felt by building arch structures. Numbers can be taught by combining ancient counting methods, making oracle bone number cards, and allowing students

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4.4 Upgrading the Evaluation and Training System to Enhance Cultural Literacy

The upgrading of the teaching evaluation system needs to break through the traditional quantitative mode and build a cultural literacy-oriented multi-dimensional evaluation mechanism. Teacher training can add a mathematical culture workshop to guide teachers to design sundial-making projects and improve their cultural teaching ability in the practice of measuring the length of sunshades of festive seasons. A cultural perception dimension should be added to the classroom observation scale to record students' spatial reasoning performance in recovering the arrangement of character molds of the Song Dynasty movable-type printing press and to focus on their innovative thinking in applying traditional wisdom to solve geometric problems. Student growth portfolios can include cultural-themed works, such as a mathematical model of a three-dimensional Spring Festival couplet made in conjunction with Chinese New Year customs, demonstrating the level of integration of symmetrical graphical understanding and folk aesthetics. School-based teaching and research activities can be carried out to evaluate lessons across disciplines, analyze the effect of cultivating a sense of quantity in the teaching of the Square Field Technique in the Nine Chapters of the Mathematical Art, and compare the differences in thinking between ancient and modern methods of area measurement. Teachers' professional development evaluation should add indicators of cultural transformation ability, for example, assessing whether their teaching design of adapting the chicken and rabbit problem of Sun Tzu's Arithmetic can guide students to reproduce the wisdom of the ancients in solving the problem using the drawing strategy. Schools can set up a database of mathematics culture teaching cases, including high-quality examples such as "The Beauty of Proportion in Dunhuang Frescoes", and form school-based evaluation standards. Regional assessments can introduce open-ended cultural topics, such as analyzing the geometric principles of mortise-and-tenon joinery in traditional architecture, and writing math field trips to replace part of the written exam. This innovation in the assessment system makes cultural literacy visible and measurable, and when students are able to explain the multiplication and distribution law using the principles of beadwork, it is a sign that mathematical culture has penetrated from the surface of knowledge to the core of thinking.

5.Conclusion

The in-depth integration of core literacy and mathematical culture has opened up a new dimension of practice for the reform of primary mathematics education. Research has confirmed that through the implementation of systematic penetration strategies, the phenomenon of "two skins" between cultural elements and subject teaching can be effectively solved, so that the mathematics classroom can be revitalized with cultural vitality. The enhancement of teachers' cultural consciousness has prompted the teaching design to break through the boundaries of technical rationality, the innovation of multiple teaching methods has reconstructed the knowledge transmission method, and the construction of three-dimensional resource network

has made the mathematical culture get a tangible dissemination carrier. More importantly, the upgrading of the evaluation system promotes the benign interaction between literacy cultivation and cultural infiltration, helping students to form a complete mathematical cognitive schema. This transformation of educational paradigm not only reshapes the ecological pattern of the mathematics classroom, but also responds to the proposition of "what kind of people should be cultivated" in a deeper sense. In the future, we need to further explore the adaptability of the strategies in different regional cultures, and continue to improve the construction of the math culture resource base, so that the core literacy can really be realized as the cultural genes and thinking qualities that students can feel and know.

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Conflict of Interests

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