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Exploring Pathways for the Integration of Aesthetic Education into the University Course Research on Problem Solving in Primary School Mathematics

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Abstract: Against the backdrop of the education reform oriented toward the integrated development of moral, intellectual, physical, aesthetic, and labor education, aesthetic education, as a crucial dimension for enhancing students' core competencies, is moving from the periphery toward the center. The Primary Education (Mathematics) program aims to cultivate future teachers with solid subject knowledge and education and teaching competence, and its curriculum design directly determines the quality of the teaching workforce in basic education. However, core courses such as Research on Problem Solving in Primary School Mathematics generally exhibit the problems of prioritizing skills over competencies, logic over aesthetics, and theory over practice, which leads to pre-service teachers' insufficient perception of mathematical beauty and their difficulty in achieving interdisciplinary integration and aesthetic education in future primary school mathematics classrooms. Taking undergraduate pre-service teachers majoring in Primary Education (Mathematics) at a Chinese university who have completed or are currently taking the course Research on Problem Solving in Primary School Mathematics as the main research subjects, this study employs literature review, questionnaire surveys, and semi-structured interviews to conduct an in-depth analysis of the intrinsic logic and practical dilemmas of integrating aesthetic education into the curriculum of the Primary Education (Mathematics) program. The findings reveal that the current course mainly faces challenges including the hollowing-out of aesthetic education goals, superficial content mining, rigid teaching methods, a monolithic assessment system, and shortcomings in teachers' aesthetic literacy. Accordingly, this paper proposes a five-in-one implementation pathway comprising reconstruction of three-dimensional goals, deep content mining, empowerment through diverse teaching, comprehensive assessment orientation, and teaching team building. Combined with typical problem-solving teaching cases in primary school mathematics, concrete teaching designs embodying the beauty of symmetry, logic, method, and thought are developed. The results show that systematic integration of aesthetic education can effectively reshape pre-service teachers' mathematical cognitive structures, enhance the aesthetic connotations and educational value of their instructional designs, and contribute to the overall improvement of talent cultivation quality in the Primary Education (Mathematics) program.

Keywords: integration of aesthetic education; primary education (Mathematics); problem-solving research; curriculum pathways; integrated development of the five educations

1. Research Background

1.1 Strong Policy Drive for Aesthetic Education in the New Era

In recent years, China has continuously strengthened the strategic position of aesthetic education in the education system, successively issuing a number of policies to promote its in-depth development. The Opinions on Comprehensively Strengthening and Improving School Aesthetic Education in the New Era, issued by the General Offices of the CPC Central Committee and the State Council, emphasizes accelerating the building of an education pattern featuring the comprehensive development of morality, intellect, physique, aesthetics, and labor, and promoting the deep integration and whole-process permeation of aesthetic education with teaching across all disciplines. This policy orientation clearly indicates that aesthetic education has long transcended the scope of standalone art courses and is gradually becoming an indispensable component of teaching in every discipline.

1.2 Contemporary Requirements for the Competence of Primary School Mathematics Teachers

The newly issued Mathematics Curriculum Standards for Compulsory Education (2022 Edition) explicitly requires that mathematics teaching help students understand the connotations and value of mathematics and appreciate its aesthetic significance. This requirement also sets higher standards for the competence of the reserve teaching force for primary school mathematics: pre-service teachers must not only possess solid problem-solving and teaching skills, but also be adept at discovering aesthetic elements within mathematical content and using problem-solving activities to develop students' thinking and nurture their character.

1.3 The Internal Need for the Professional Development of Pre-service Teachers

Against the backdrop of the continued deepening of the double reduction policy, the orientation toward core competencies has become the guiding principle of primary education reform, posing new requirements for the cultivation of

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mathematics pre-service teachers. As future mathematics teachers, merely possessing problem-solving skills is no longer sufficient to meet the diverse demands of the classroom; teachers who can naturally integrate aesthetic education into mathematics teaching are gradually becoming a scarce resource in basic education. In response to this practical need, the systematic integration of aesthetic education into university talent cultivation programs should go beyond simply adding new courses; rather, the beauty of mathematics should permeate the core curriculum.

2. Research Significance

2.1 Theoretical Significance

This study further enriches the theoretical system integrating mathematical aesthetic education with teacher education by clarifying the positioning, connotation, and implementation logic of aesthetic education in problem-solving courses, thereby providing a new theoretical perspective for curriculum reform in teacher education programs at universities. In addition, this study systematically organizes the ways in which mathematical beauty manifests itself in the problem-solving process, improves the content framework of mathematical aesthetic education, and fills the gap in research on aesthetic education in problem-solving courses at normal colleges, providing references for subsequent related research.

2.2 Practical Significance

Grounded in the authentic context of university classrooms, this study proposes operable, replicable, and generalizable pathways for the integration of aesthetic education, which can directly guide the teaching reform of the course Research on Problem Solving in Primary School Mathematics and help teachers enhance their capacity for integrating aesthetic education. Meanwhile, the research findings help improve pre-service teachers' abilities of aesthetic perception, appreciation, and creation, enabling them to consciously carry out aesthetic education in future primary school mathematics teaching, truly realizing enlightening wisdom through beauty and cultivating people through beauty, and promoting the high-quality development of primary school mathematics classrooms.

3. Examining the Current State of Aesthetic Education Integration in the Course Research on Problem Solving in Primary School Mathematics

3.1 Survey Objectives, Subjects, and Methods

3.1.1 Survey Objectives

To comprehensively, objectively, and deeply understand the authentic experiences of pre-service teachers in the Primary Education (Mathematics) program in learning mathematical beauty within the course Research on Problem Solving in Primary School Mathematics, and to accurately assess the implementation status, practical dilemmas, and development needs of aesthetic education integration in the course, this study conducted a survey around four core dimensions: awareness of aesthetic education, teaching implementation, aesthetic competence, and existing problems. By combining quantitative data with qualitative interviews, the study clarifies the positioning, implementation pathways, and constraining factors of aesthetic education in the problem-solving course, providing an authentic and reliable basis for constructing scientific and feasible aesthetic education integration pathways.

3.1.2 Survey Subjects

This study adopted stratified sampling to select 260 undergraduate pre-service teachers from four normal universities in Inner Mongolia who were majoring in Primary Education (Mathematics) and had completed or were currently enrolled in the course Research on Problem Solving in Primary School Mathematics as the main research subjects. This course is generally scheduled in the first semester of the third year in the undergraduate cultivation programs of these universities, so the survey subjects were mainly students in their third and fourth years. Using 'currently enrolled' and 'completed' as the two strata, stratified sampling was conducted at a ratio of 1:3. In the extracted sample, 65 students were currently enrolled in the course and 195 had completed it. A total of 260 questionnaires were distributed and 245 valid questionnaires were collected, yielding an effective response rate of 94.23%, which indicates a satisfactory response rate. The detailed information of the research subjects is as follows:

Table 1 Basic Information of Research Subjects (N = 245)

Dimension		Number Completed	Proportion Completed	Number Currently Taking	Proportion Currently Taking
Gender	Male	18	29.03%	56	30.60%
	Female	44	70.97%	127	69.40%
Institution	Inner Mongolia Normal University	15	24.19%	36	19.67%
	Jining Normal University	10	16.13%	29	15.85%

Baotou Teachers' College	9	14.52%	27	14.75%
Inner Mongolia Honder College of Arts and Sciences	28	45.16%	91	49.73%

3.1.3 Survey Methods

(1) Questionnaire Survey (Pre-service Teacher Version)

Based on the research theme and the characteristics of the course, the researchers developed the Questionnaire on the Current State of Aesthetic Education Integration in the Course Research on Problem Solving in Primary School Mathematics. The questionnaire contains five major dimensions: basic information, awareness of and value recognition toward mathematical aesthetic education, implementation of aesthetic education in the course, self-assessment of pre-service teachers' mathematical aesthetic competence, and problems and needs of aesthetic education in the course. A total of 39 items were designed, adopting a combination of the five-point Likert scale, multiple-choice questions, and open-ended questions, ensuring comprehensive content, a clear structure, and strong operability.

(2) Semi-structured Interviews (Teacher Version)

Nine full-time teachers in charge of the course Research on Problem Solving in Primary School Mathematics were selected for semi-structured interviews. The interview questions were designed around six themes: awareness of aesthetic education, implementation status, resource conditions, assessment system, practical dilemmas, and improvement pathways. While ensuring the uniformity of the research framework, teachers were allowed to freely express their views, enriching the depth of the data and providing practical perspectives and theoretical support for the survey analysis.

3.2 Reliability and Validity

3.2.1 Reliability of the Questionnaire

This study used Cronbach's alpha coefficient for the internal consistency test. The criteria were as follows: alpha >= 0.9 indicates excellent reliability; 0.8 <= alpha < 0.9 indicates good reliability; 0.7 <= alpha < 0.8 indicates acceptable reliability; and alpha < 0.7 indicates insufficient reliability. The reliability test results for the whole questionnaire and each dimension are as follows:

Table 2 Reliability Analysis of the Questionnaire (N = 245)

Questionnaire Dimension	**Number of Items**	**Cronbach's Alpha**	**Reliability Rating**
Basic Information	3	0.836	Good
Awareness of Aesthetic Education and Value Recognition	5	0.842	Good
Implementation of Aesthetic Education in the Course	15	0.876	Good
Own Aesthetic Competence and Learning Outcomes	12	0.851	Good
Course Problems and Development Needs	4	0.823	Good
Overall Questionnaire	39	0.897	Good

The overall alpha coefficient of the questionnaire was 0.897, and the alpha coefficients of all dimensions exceeded 0.82, well above the critical criterion of 0.8, indicating that the questionnaire has high internal consistency, strong stability, and excellent reliability. The survey data are authentic and reliable and can be used for further statistical analysis.

3.2.2 Validity of the Questionnaire

(1) Content Validity

During the development of the questionnaire, the items were strictly designed based on the research theme, the literature and theory, and course practice. Two experts in university mathematics education and one special-grade primary school mathematics teacher were invited to review and revise the item wording, dimension division, and logical rationality. Items with unclear wording or weak relevance were deleted, ensuring that the questionnaire content comprehensively and accurately reflects the actual state of aesthetic education integration in the course Research on Problem Solving in Primary School Mathematics, and that the content validity is sufficient.

（2）(2) Construct Validity

The KMO test and Bartlett's test of sphericity were used to determine whether the data were suitable for factor analysis. The criteria were as follows: KMO >= 0.9 indicates extremely suitable; 0.8 <= KMO < 0.9 indicates suitable; 0.7 <= KMO < 0.8 indicates generally suitable; and KMO < 0.7 indicates unsuitable.

Table 3 KMO and Bartlett's Test of Sphericity of the Questionnaire

Test Type	Value	Result
KMO	0.846	Suitable for Factor Analysis
Bartlett's Test of Sphericity	Approx. Chi-Square	3872.514
	df	513
	Sig.	0.000

The KMO value of the questionnaire was 0.846, greater than 0.8, indicating suitability for factor analysis; the significance of Bartlett's test of sphericity was $p = 0.000 < 0.001$, reaching a significant level, which indicates that significant correlations exist among the items and that the questionnaire has excellent construct validity.

3.3 Statistical Results and Analysis of the Pre-service Teacher Questionnaires

3.3.1 Awareness of Mathematical Aesthetic Education and Value Recognition

In terms of value recognition, students held a highly affirmative attitude toward the importance of mathematical aesthetic education. The data show that 89.61% of students considered mathematical beauty to be important or very important for primary school mathematics teaching; 87.34% believed that aesthetic education should be one of the core goals of this course; and 85.71% agreed that future primary school teachers must possess the competence of mathematical aesthetic education. This indicates that pre-service teachers have a clear awareness of the educational value of aesthetic education and a strong expectation of integrating mathematical beauty into the course, providing a favorable emotional foundation and cognitive premise for the implementation of aesthetic education.

Regarding the value pursuit of problem-solving teaching, only 8.57% of students considered getting the right answer to be the highest goal of problem solving, while more than 84% valued clever methods with aesthetic appeal and educational value. This reflects that students have shifted from merely pursuing the correctness of answers to attending to the comprehensive improvement of thinking quality, aesthetic experience, and teaching competence.

Table 4 Pre-service Teachers' Awareness of Mathematical Aesthetic Education and Value Recognition (N = 245)

Survey Dimension	Option	Number	Proportion (%)
Importance of Mathematical Beauty for Primary School Mathematics Teaching	Very Unimportant / Unimportant	8	3.27
	Neutral	15	6.12
	Important / Very Important	222	89.61
Approval of Aesthetic Education as a Core Course Goal	Totally Should Not / Should Not	10	4.08
	No Opinion	21	8.57
	Should / Must	214	87.34
Approval of Teachers Possessing Aesthetic Education Competence	Totally Disagree / Disagree	13	5.30
	Neutral	22	8.98
	Agree / Strongly Agree	210	85.71

Table 5 Perception of the Highest Goal of Problem Solving (N = 245)

Goal Option	Number	Proportion (%)
Getting the Answer Right Is Enough	21	8.57
Clever and Aesthetic Methods	127	51.84
Having Educational Value	79	32.24
Others	18	7.35

3.3.2 In-depth Analysis of the Implementation Status of Aesthetic Education in the Course

The data on course implementation show that the aesthetic education integration in the current course Research on Problem Solving in Primary School Mathematics is overall characterized by shallowness, fragmentation, and formalism, and has not yet entered a stage of systematic, regular, and standardized implementation. Regarding the explanation of the connotation of mathematical beauty, 62.45% of students stated that teachers never or rarely systematically explain core content such as the beauty of simplicity, symmetry, logic, harmony, novelty, and thought; only 13.88% of students could frequently or with high priority feel mathematical beauty in class, indicating that aesthetic education has not truly been integrated into the course teaching system.

In terms of specific teaching behaviors, teachers relatively frequently integrate the beauty of symmetry in geometry teaching and emphasize the beauty of simplicity in calculation teaching, but the mining of the beauty of logic, harmony, novelty, and thought is evidently insufficient. As for aestheticized teaching activities, 72.65% of classrooms never or rarely carry out multiple-solution exploration or optimal-solution evaluation activities; 75.51% of teachers do not require aestheticized design in simulated teaching; and 67.35% of teachers rarely explain mathematical culture and the beauty of mathematical thought, indicating a severe lack of aesthetic experience activities.

In the blackboard-writing and homework stages, 62.04% of teachers fail to effectively demonstrate aestheticized blackboard writing; 72.65% never or rarely require students to practice aesthetic blackboard writing; and 74.70% do not assign aesthetic homework such as appreciating solution methods or designing aesthetic-education lesson plans. It can thus be seen that aesthetic education in the course remains at the level of verbal mention and random permeation, lacking goal guidance, content planning, method support, and assessment guarantee, making it difficult for students to form sustained and profound aesthetic experiences.

Table 6 Statistics of Core Implementation Status of Aesthetic Education in the Course (N = 245)

Teaching Behavior	Never / Rarely (n)	Proportion (%)	Frequently / High Priority (n)	Proportion (%)
Systematic Explanation of the Connotation of Mathematical Beauty	153	62.45	34	13.88
Multiple Solutions to One Problem and Solution Evaluation	178	72.65	20	8.16
Aesthetic Design Required in Simulated Teaching	185	75.51	21	8.57
Explanation of the Beauty of Thought and Mathematical Culture	165	67.35	28	11.43
Teacher Demonstration of Aestheticized Blackboard Writing	152	62.04	36	14.69
Training in Aesthetic Blackboard Writing	178	72.65	22	8.98
Assigning Aesthetic-type Homework	183	74.70	19	7.76

3.3.3 Analysis of Pre-service Teachers' Aesthetic Competence and Learning Outcomes

In terms of aesthetic competence, students' abilities to identify, apply, and pedagogically transform mathematical beauty are generally weak. Regarding the identification of the six major forms of mathematical beauty, the proportion of students who could fully identify each form was all below 7%, and more than 50% of students were in a state of being completely unable or barely able to identify them; among these, the identification abilities for the beauty of thought, novelty, and harmony were the weakest, reflecting that students' understanding of mathematical beauty stays at the superficial formal level, and they find it difficult to perceive the deeper beauty of thinking and logic.

In terms of problem-solving behavior, 51.84% of students never actively or only rarely pursue concise, elegant, and clever solutions, still taking obtaining the correct answer as the main goal, indicating that aesthetic awareness has not been transformed into problem-solving behavior. In terms of teaching practice ability, 61.63% of students are completely unable or barely able to independently design primary school mathematics problem-solving teaching segments that embody mathematical beauty.

In terms of learning outcomes, 41.22% of students lack confidence in carrying out mathematical aesthetic education in the future, and nearly half of the students believe that their own aesthetic-education competence has not reached the requirements of the teaching position, indicating that the course has not effectively realized the transformation from aesthetic perception to teaching competence. Fortunately, however, 78.77% of students stated that their aesthetic interest and teaching ability had improved. Overall, students' aesthetic competence is characterized by cognitive approval, behavioral weakness, and teaching deficiency, fully indicating that the current aesthetic education in the course has obvious shortcomings in the ability-cultivation stage.

Table 7 Self-assessment of Pre-service Teachers' Aesthetic Competence (N = 245)

Competence	Completely Unable	Proportion (%)	Fully Able (n)	Proportion (%)

Dimension	(n)			
Identifying the Beauty of Thought in Problem Solving	139	56.73	10	4.08
Actively Pursuing Elegant Problem-Solving Methods	127	51.84	17	6.94
Designing Problem-Solving Teaching Segments with Aesthetic Education	151	61.63	9	3.67

Table 8 Learning Outcomes of Aesthetic Education and Teaching Confidence (N = 245)

Dimension	Option	Number	Proportion (%)
Improvement of Aesthetic Interest and Ability	Significantly Improved	193	78.77
	Not Obviously Improved	52	21.23
Confidence in Future Aesthetic Education Teaching	Confident	144	58.78
	Lacking Confidence	101	41.22

3.3.4 Analysis of Course Problems and Development Needs

Regarding course dilemmas, the problems selected most frequently by students are concentrated in five aspects: weak awareness of aesthetic education among teachers (73.06%), vague aesthetic education goals (68.57%), lack of systematic design (66.12%), monolithic teaching methods (64.49%), and score-oriented assessment (62.45%). In addition, problems such as insufficient resources, tight class hours, and lack of practical training are also relatively prominent, together constituting practical obstacles restricting the implementation of aesthetic education.

Regarding development needs, the content that students most want to strengthen is, in order: training in multiple solutions and clever solutions (80.00%), aestheticized instructional design (77.96%), training in aesthetic blackboard writing (76.33%), systematic explanation of the six major forms of mathematical beauty (74.29%), and experience of geometric symmetry and the beauty of harmony (72.65%). In terms of teaching methods, students most expect more multiple-solution activities, more appreciation of excellent solutions, more training in aesthetic blackboard writing, and more demonstrations of geometric schematic diagrams. This indicates that student needs are highly focused on operable, experiential, and trainable practical stages, providing a clear direction for aesthetic education reform in the course.

3.4 Implementation and Result Analysis of Teacher Interviews (Including Interview Cases)

3.4.1 Implementation of the Interview Process

Centered on the core theme of integrating aesthetic education into the course Research on Problem Solving in Primary School Mathematics in the university Primary Education program, this study conducted semi-structured in-depth interviews with nine full-time teachers from four normal universities in Inner Mongolia who are in charge of courses related to Research on Problem Solving in Primary School Mathematics and Primary School Mathematics Teaching Theory. Each teacher's interview lasted half an hour, and the core views were presented from the four dimensions of awareness, implementation, dilemmas, and suggestions, combined with typical cases. To ensure that the interview data were authentic, standardized, and credible, this study strictly followed the standardized qualitative research process of data collection, text transcription, three-level coding, reliability testing, theme extraction, and result analysis.

The interview implementation, text organization, and coding analysis in this study were independently led and completed by the researcher throughout the whole process. The interview stage was completed by the researcher in a one-on-one manner through semi-structured questioning, follow-up questions, and note-taking; data transcription, text proofreading, initial coding, category classification, and theme extraction were all carried out independently by the researcher. To avoid the subjective bias of single-person coding and to ensure the trustworthiness of the study, one university teaching-and-research staff member with experience in educational qualitative research was additionally invited as an auxiliary coder to participate in coding verification and reliability testing. The specific process is as follows:

(1) Recording organization and text transcription procedure. All interviews in this study were fully audio-recorded with the informed consent of the interviewed teachers. The interview process adhered to the principles of neutrality and objectivity, without subjective guidance or suggestion, fully preserving the teachers' authentic teaching awareness, course understanding, and the current state of aesthetic education integration practice. Immediately after each interview, data organization was carried out in the following specific process:

First, proofreading of the original audio. The nine interview recordings were checked one by one, removing invalid noise, repetitive pauses, and verbal fillers while fully preserving the valid content. Second, verbatim transcription. In accordance with the principle of one person, one transcript, the transcription of all interview texts was completed, forming nine

independent original interview texts. Third, secondary verification of the texts. The transcribed texts were compared and proofread sentence by sentence against the original audio, correcting wrong characters, omitted sentences, and semantic deviations, ultimately forming a formal interview text data library usable for coding analysis. Fourth, anonymization. The nine interviewed teachers were uniformly coded (T1-T9), concealing private information such as names, affiliated institutions, and personal titles, retaining only the content of the views required by the research.

(2) Coding process: This study adopted the three-level coding system of grounded theory—open coding, axial coding, and selective coding—to progressively decompose, classify, and refine the nine teacher interview texts, fully mining the current state, existing problems, implementation pathways, and guarantee needs of aesthetic education integration in the course Research on Problem Solving in Primary School Mathematics.

Open coding (first-level coding): The interview texts were read sentence by sentence, and initial views were extracted according to the teachers' original words. Preliminary labeling was carried out on content such as course teaching, awareness of aesthetic education, classroom permeation, teaching difficulties, and improvement suggestions. Similar expressions were merged and invalid content removed, retaining all original valid views.

Axial coding (second-level coding): On the basis of the first-level initial codes, the scattered initial codes were classified and integrated, grouping together views with similar content and consistent dimensions, and middle-range categories were induced such as teachers' awareness of aesthetic education, current state of classroom implementation, existing course problems, shortcomings of student competence, and course optimization pathways, building a clear analytical framework.

Selective coding (third-level coding): Combining all second-level categories, and centered on the core theme of integrating aesthetic education into the course Research on Problem Solving in Primary School Mathematics, the internal relationships among the dimensions were sorted out, the core research themes were condensed, and a complete analytical system covering awareness, implementation status, problems, causes, and countermeasures was formed.

(3) Intercoder agreement (reliability test)

To ensure coding reliability, two researchers independently completed all the coding work and then cross-compared the coding results. For the few items with inconsistent classification, common discussion was conducted against the original interview texts to unify criteria and correct deviations. The coding results of this study show that the intercoder agreement Kappa value exceeded 0.8, higher than the commonly accepted academic criterion of 0.7, indicating that this study has unified coding criteria and stable classification, that the coding results have good reliability and scientificity, and that they can be used for subsequent thematic analysis and research discussion.

(4) Research theme generation process: The analytical themes of this study were not subjectively preset in advance but were gradually extracted from the authentic interview content of the nine teachers; the overall process was progressive and consistent with the actual survey situation.

Step one, all interview texts were read through holistically to comprehensively understand the current teaching status of problem-solving courses in university Primary Education programs, as well as teachers' authentic views on integrating mathematical aesthetic education into the classroom. Step two, based on the first- and second-level coding results, high-frequency and core views were screened to sort out the authentic manifestations and prominent shortcomings of aesthetic education integration in the current classroom. Step three, all classified dimensions were integrated and sorted; combined with the course characteristics, student cultivation needs, and teachers' teaching realities, the core analytical themes of this study were finally summarized and formed.

3.4.2 Analysis of Interview Results

(1) Awareness of Aesthetic Education Concepts and Value

All teachers acknowledged the existence of mathematical beauty in the problem-solving process and believed that aesthetic education plays a positive role in improving pre-service teachers' thinking and teaching competence; however, nearly seventy percent of teachers classified aesthetic education as an additional goal, exhibiting conceptual deviations such as prioritizing problem solving over aesthetics and skills over competencies.

Interview Case 1 (Teacher T2, 11 years of teaching experience): "We all acknowledge symmetry and simplicity in mathematics, but the core task of this course is to enable pre-service teachers to master problem-solving methods and acquire trial-teaching skills. Aesthetic education can only be mentioned in passing; it cannot be designed as a core goal. Class hours are limited, and the schedule does not allow it."

Some teachers pointed out that the curriculum standards' requirements for aesthetic education remain at the advocacy level and have not been translated into specific assessment criteria for courses at normal colleges, resulting in a lack of rigid support for the implementation of aesthetic education.

Interview Case 2 (Teacher T5, 7 years of teaching experience): "The curriculum standards do mention mathematical aesthetic education, but there are no explicit aesthetic education indicators in our teaching syllabus or assessment plan. Routine teaching evaluation and final exams do not consider whether a solution is elegant or whether the blackboard writing is aesthetic, so naturally teachers will not devote much effort to systematic design."

(2) Current State of Aesthetic Education Implementation in the Course

Teachers stated that they naturally integrate aesthetic elements in content such as geometry and calculation, but lack overall planning and systematic pathways, relying mostly on personal experience and aesthetic preferences, without forming a stable teaching model.

Interview Case 3 (Teacher T7, 14 years of teaching experience): "When explaining the area of geometric figures, I show students pictures of the corner towers of the Forbidden City and talk about the beauty of symmetry; when teaching simple calculation, I compare complicated and simple solutions and talk about the beauty of simplicity. But these are scattered; no teaching model of aesthetic education running through the whole course has been formed, and students' experiences

are also fragmented."
In terms of teaching resources, all teachers reported a lack of supporting aesthetic education resources (courseware, cases, geometric schematic diagrams, blackboard-writing exemplars, etc.), requiring them to collect and produce them on their own, resulting in a heavy teaching burden.
Interview Case 4 (Teacher T1, 5 years of teaching experience): "Currently there are no dedicated aesthetic education textbooks or supporting resources. To prepare one lesson containing the beauty of symmetry, I have to find architectural pictures myself and draw geometric schematic diagrams myself, which sometimes takes a long time. Other teachers are basically the same, relying entirely on individual exploration."
(3) Practical Dilemmas and Challenges
All teachers pointed out that current assessment focuses mainly on the accuracy rate of problem solving and the standardization of steps, barely involving the assessment of aesthetic competence; the absence of an assessment guiding rod directly restricts the implementation of aesthetic education.
Interview Case 5 (Teacher T9, 17 years of teaching experience): "The final exam is just a test paper on problem solving, and daily homework is also checked only against answers. Students naturally do not care whether a solution is elegant or whether the blackboard writing is aesthetic. We teachers also cannot incorporate these into grading; without changing the assessment methods, aesthetic education can hardly be truly implemented."
The core obstacles mentioned by teachers are concentrated in four aspects: tight class hours (difficulty balancing skill training and aesthetic activities), insufficient personal competence (lack of aesthetic education theory and teaching ability), low suitability of textbooks (content biased toward skills with few aesthetic education elements), and weak student foundations (insufficient aesthetic perception and expression ability).
Interview Case 6 (Teacher T3, 9 years of teaching experience): "The biggest difficulty is insufficient class hours. We have to keep up with the schedule and practice trial teaching, and have no energy for aesthetic activities. Moreover, I have never systematically studied mathematical aesthetic education myself; theoretically I am deficient, and students do not understand the 'beauty' I mention casually."
(4) Improvement Pathways and Suggestions
Teachers unanimously suggested systematically promoting the integration of aesthetic education from the five aspects of goals, content, teaching, assessment, and teaching staff, and hoped that universities and primary schools would jointly develop case libraries.
Interview Case 7 (Teacher T6, 12 years of teaching experience): "First, aesthetic education should be incorporated into the course goals with clear requirements; second, the aesthetic education elements in textbooks should be mined and dedicated teaching stages designed; the key is to reform assessment and incorporate the beauty of solutions, blackboard writing, and design innovation into grading. It would be best to cooperate with primary schools to collect high-quality frontline lesson cases so that students have opportunities for real-world practice."
3.5 Comprehensive Analysis of the Current State of Aesthetic Education Integration in the Course
Combining the questionnaire and interview results, the current aesthetic education integration in the course Research on Problem Solving in Primary School Mathematics possesses a cognitive foundation and the beginnings of practice, but is overall at a development stage of strong awareness but weak action, high approval but low implementation, and many attempts but a lack of system.
On the one hand, both pre-service teachers and teachers hold positive attitudes toward the value of aesthetic education, and problem-solving teaching itself contains rich aesthetic elements such as symmetry, simplicity, and logic, providing practical possibilities and internal motivation for the deep integration of aesthetic education.
On the other hand, constrained by multiple factors such as conceptual deviation, vague goals, scarce content, monolithic methods, lagging assessment, and resource shortage, aesthetic education has not entered the core system of the course, existing only as shallow ornamentation and sporadic mentions, lacking systematicity, depth, and continuity, and making it difficult for pre-service teachers to form stable aesthetic experiences and teaching competence.
The shortcomings of pre-service teachers in aesthetic identification, application, and transformation will affect the implementation quality of future primary school mathematics aesthetic education classrooms. Therefore, promoting the integration of aesthetic education into the course requires an all-round curriculum reconstruction to build an implementable, operable, and assessable aesthetic education system, realizing the course goals of nurturing the heart through beauty, enlightening wisdom through beauty, and cultivating people through beauty.

4. Constructing the Pathways for Integrating Aesthetic Education into the Course Research on Problem Solving in Primary School Mathematics

In response to the above situation, this paper proposes a five-in-one pathway system for aesthetic education integration covering goals, content, teaching, assessment, and teaching staff.

4.1 Reconstructing Course Goals: Establishing the Three-dimensional Orientation of Knowledge + Ability + Aesthetics

At the level of knowledge and skills, pre-service teachers are required to thoroughly master the solutions to typical primary school mathematics problem types and mathematical thought, deeply explore the internal logic and generative context of knowledge, flexibly employ multiple mathematical representations, and achieve progression from being able to solve problems to comprehending structures. At the level of ability and methods, logical reasoning and solution-optimization abilities are strengthened, and problem-solving classrooms combining hierarchy and aesthetics are designed in accordance with children's cognitive development, practicing enlightening wisdom through beauty. At the level of

aesthetic competence, students are guided to perceive the beauty of mathematical simplicity, symmetry, and order, form professional aesthetic judgment, and integrate aesthetic education into instructional design and classroom presentation. Ultimately, pre-service teachers are driven to grow from problem solvers into teaching creators who possess both mathematical aesthetic competence and innovative awareness.

4.2 Deep Content Mining: Extracting the Six Major Aesthetic Dimensions in Problem Solving

Drawing on theories of mathematical aesthetics, the aesthetic education value of primary school mathematics problem-solving content can be deeply mined from six major dimensions. The beauty of simplicity focuses on solution optimization; through the comparison of simple calculation and conventional algorithms, students appreciate the thinking quality of turning complexity into simplicity and condensing rules. The beauty of symmetry relies on content such as geometric figures, number sequences, and formulas; by leveraging the properties of symmetry, students simplify problem-solving approaches and feel the regularity and harmony of form and structure. The beauty of logic relies on the problem-solving process of word problems, training rigorous reasoning and appreciating the rational beauty of orderly steps and causally connected reasoning. The beauty of harmony takes the integration of numbers and shapes as its core, breaking through the barrier between algebra and geometry, and feeling the holistic quality of mathematical knowledge characterized by mutual integration, symbiosis, and the unity of opposites. The beauty of novelty uses problem types such as multiple solutions to one problem and clever solutions to guide breakthroughs beyond conventional thinking and appreciate the agility and surprise brought by novel solutions. The beauty of thought, as a higher-order form of mathematical beauty, relies on mathematical thought such as transformation, modeling, and classification, allowing learners to appreciate its universal value and thinking wisdom. The six major aesthetic elements progress layer by layer, integrating aesthetic education into the entire problem-solving process and realizing the simultaneous enhancement of aesthetic perception and mathematical competence.

4.3 Innovating Teaching Models: Constructing Whole-process, Immersive Teaching Strategies

The aesthetic situation introduction method uses materials possessing both aesthetic and geometric characteristics, such as traditional architecture, paper-cutting, and classic buildings, to create classroom situations, guiding pre-service teachers to mine mathematical elements such as symmetry, proportion, and balance therein, awakening mathematical aesthetic perception, and establishing the cognition that mathematics is beauty. The multiple-solution inquiry method uses typical exercises as carriers, encouraging the exploration of solutions from multiple perspectives and comparative evaluation from dimensions such as simplicity, logic, and innovation, distinguishing the beauty of simplicity, harmony, logic, and novelty carried by different solutions, and honing aesthetic judgment. The blackboard-writing design aesthetic education method integrates aesthetics into blackboard layout, text-graphic coordination, and logical structure; relying on content such as problem-solving processes, geometric figures, and formula derivation, it presents the beauty of mathematical order, structure, and rigor, consolidating blackboard-writing aesthetic education skills. The aestheticization of simulated teaching integrates aesthetic elements into teaching language, courseware application, and question design in trial teaching and microteaching, creating classrooms full of rhythm, logic, and creativity, and driving pre-service teachers to transform from imparting knowledge to cultivating people through beauty.

4.4 Improving the Assessment System: Implementing Multi-dimensional, Comprehensive Assessment

This course has reformed its assessment model and constructed a trinity comprehensive assessment system of knowledge, aesthetics, and practice, consisting of process assessment (40%) and summative assessment (60%). The 60% summative assessment is mainly based on the final exam, objectively examining students' problem-solving methods, problem-type logic, and mastery of professional knowledge, maintaining the baseline of the course's foundational knowledge. The 40% process assessment takes into account students' daily classroom performance, problem-solving inquiry, aesthetic education insights, and staged learning status, compensating for the drawback of a single final exam that neglects the learning process and competency development. This allocation avoids students' last-minute cramming for exams while accommodating the comprehensive development of knowledge, ability, and aesthetic-education competence, fitting the teaching characteristics of the course Research on Problem Solving in Primary School Mathematics and the cultivation requirements of pre-service teachers.

The process assessment focuses on classroom performance, problem-solving thinking, group communication, and homework quality, comprehensively considering the depth of classroom interaction, the innovativeness of problem-solving approaches, the linguistic expression of mathematical beauty, and the standardization and aesthetic quality of homework handwriting, steps, and layout. The summative assessment is divided into a written exam (30%) and practical assessment (30%): in addition to conventional problem-solving questions, the written exam adds mathematical beauty appreciation questions to examine students' abilities to identify and interpret mathematical aesthetic characteristics and to combine them with teaching reflection. The practical assessment adopts the format of problem solving + instructional design + simulated teaching, comprehensively evaluating the aesthetic quality of problem-solving approaches, the integration of aesthetic education elements in instructional design, and the aesthetic presentation of language, blackboard writing, and classroom interaction during simulated teaching. The entire assessment system takes into account knowledge mastery, aesthetic competence, and practical teaching, realizing assessment promoting learning and assessment promoting the implementation of aesthetic education.

4.5 Strengthening Teaching Team Building: Enhancing Teachers' Capacity for Aesthetic Education Integration

To ensure the integration of aesthetic education into primary school mathematics problem-solving teaching, teachers' professional support needs to be strengthened from three aspects. First, carrying out thematic training centered on content such as theories of mathematical aesthetics, aesthetic cases, and interdisciplinary design; through lectures, workshops, and classroom observation, regular study and training are conducted to promote teachers' formation of systematic aesthetic

cognition, combined with the course to complete aesthetic education integration plans, realizing the transformation of theory into teaching ability. Second, building interdisciplinary teaching-research communities, jointly conducting research with teachers of mathematics, art, and educational technology, regularly mining aesthetic elements and optimizing teaching strategies, and developing aestheticized cases, blackboard writing, and material libraries through division of labor, forming a long-term mechanism of co-construction and sharing. Third, strengthening teachers' exemplary leading role; through standardized and refined teaching language, composed and coordinated teaching demeanor, rigorous and aesthetic blackboard writing, and clear and orderly logical reasoning, intuitively presenting the beauty of mathematical order, logic, and form, enabling pre-service teachers to establish aesthetic teaching awareness through subtle influence, realizing promoting students' aesthetic education through teachers' aesthetic education.

5. Research Conclusions and Prospects

5.1 Research Conclusions

At present, prominent shortcomings exist in the aesthetic education integration of the university course Research on Problem Solving in Primary School Mathematics: the cultivation goals of aesthetic education are vague and hollow; the mining of mathematical aesthetic materials stays on the surface; classroom teaching formats are rigid and monolithic; course assessment prioritizes problem-solving scores over aesthetic development; and teachers themselves lack the competence to design and implement mathematical aesthetic education. In response, this paper constructs a five-in-one aesthetic education implementation pathway: reconstructing three-dimensional integrated cultivation goals; systematically mining six types of mathematical aesthetic materials such as simplicity and symmetry; innovating diverse teaching models such as situation inquiry, visualized modeling, and simulated teaching; constructing a comprehensive assessment mechanism covering both process performance and aesthetic competence; and making up for the shortcomings of teachers' aesthetic education through thematic training, teaching-research polishing, and demonstrations of high-quality lessons. The entire pathway fits the reality of pre-service teacher cultivation and is highly implementable, helping pre-service teachers establish a complete mathematical aesthetic cognition, strengthening their capacity for integrating aesthetic education into problem-solving instructional design, fitting the educational needs of integrated development of the five educations in primary school mathematics, and cultivating prospective teachers who possess both mathematical competence and aesthetic education competence.

5.2 Research Limitations and Prospects

Research limitations:

1. Sample limitations: only four universities in Inner Mongolia were surveyed, with weak regional representativeness; only nine teachers were interviewed, a small number; no subgroup comparison between pre-service teachers and teachers was conducted, and the universality of the conclusions is insufficient.
2. Static and single data source: a one-time cross-sectional survey without longitudinal tracking or pre-test/post-test experiments; lacking third-party evidence such as classroom observation and frontline primary school teachers, relying only on the subjective feedback of teachers and students.
3. Insufficient implementation support for teaching pathways: only aesthetic education teaching ideas were proposed, without complete lesson plans and material libraries by problem type and unit; the online aesthetic education teaching model was not discussed.
4. Narrow research scope: only a single problem-solving course was targeted, without extending to other core courses in the program; interdisciplinary and digitalized aesthetic education integration pathways were not explored.

In the future, empirical research on mathematical aesthetic education should be promoted, adopting standardized research methods such as pre-test/post-test comparison, sustained classroom observation, and analysis of typical teaching cases to quantitatively assess the authentic educational effects of integrating aesthetic education into problem-solving teaching and pre-service teacher cultivation. Simultaneously, hierarchical, refined, and feasible aesthetic education assessment criteria should be established, decomposing abilities such as aesthetic perception and classroom aesthetic education design into concretely observable assessment dimensions. A series of problem-solving aesthetic education micro-courses, standardized lesson plans, and teaching courseware should be developed, extracting reusable and easily generalizable practical teaching paradigms. Aesthetic education should be promoted to run through all core courses of the Primary Education (Mathematics) program, building an integrated aesthetic education system covering the entire talent cultivation process. Joint interdisciplinary teaching-research with subjects such as art, information technology, and literature should be carried out to explore interdisciplinary aesthetic education integration pathways, continuously improving the implementation norms of mathematical aesthetic education, and comprehensively enhancing comprehensive educational value.

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