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Research on the Cognitive Degree of Pre-service Junior High School Mathematics Teachers for Geometric Intuition Literacy in China

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Currently, geometric intuition literacy has attracted extensive attention from all walks of life. Many relevant problems about it have been studied except the cognitive degree of geometric intuition literacy of pre-service junior high school mathematics teachers. In this study, 40 pre-service junior high school mathematics teachers in China are surveyed using an open-ended interview method. The analysis of the data reveals that: (1) The accuracy of the cognition about geometric intuition literacy is not high. (2) The cognitive scope of pre-service high school mathematics teachers about geometric intuition literacy is not extensive and pre-service teachers' knowledge of geometric intuition literacy is focused on the more generalized elements. (3) The cognition of many pre-service teachers is not deep or comprehensive and concentrates at a lower level. (4) The cognition of many pre-service teachers for many aspects of geometric intuition literacy is not very clear. Therefore, it is suggested that: Teacher training schools should reform their curricula and pay attention to teacher trainees' learning and education on geometric intuition literacy. Special training and education on core literacy should be strengthened in pre-service teacher training so that

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geometric intuition literacy can be valued. Pre-service junior high school mathematics teachers should actively learn and study core literacy to improve their understanding of geometric intuition literacy.

Keywords: Pre-service teachers; geometric Intuition literacy; cognitive degree.

1. INTRODUCTION

Geometric intuition refers to the awareness and habit of using diagrams to describe and analyze problems. The position and form of objects in life are closely related to geometric intuition, and mathematical thinking also requires the use of intuition. In addition, geometric intuition helps students to understand mathematics visually and plays an important role in the learning process of mathematics. The Curriculum Standards for Compulsory Education in Mathematics (2022 Edition) (hereinafter referred to as The Curriculum Standards (2022 Edition)) promulgated by the Ministry of Education of the People's Republic of China in 2022 emphasizes that geometric intuition is an important means of identifying and formulating problems, analyzing and solving problems, helping to grasp the essence of problems and clarifying pathways of thinking, and clearly states that geometric intuition literacy should be fully implemented at junior high school level [1]. However, after extensive discussions and studies by many scholars and teachers on the current situation of high school students' cognition of geometric intuition literacy, it is found that the current level of geometric intuition literacy among high school students is not high, which showed that geometric intuition literacy has not been well implemented in actual teaching [2]. What are the reasons for this? How to develop students' geometric intuition literacy? This is a question worthy of our study.

2. LITERATURE REVIEW

Currently, there have been many studies on this issue of implementing geometric intuition literacy in high school mathematics teaching, and a literature review reveals that the relevant studies mainly focus on two aspects: the current situation of geometric intuition literacy among high school students and the cultivation strategies.

2.1 The Situation of High School Students' Geometric Intuition Literacy Level

Before and after the promulgation of The Curriculum Standards (2022 Edition), various scholars investigated the current state of geometric intuition literacy levels of middle school students. The analytical framework for measuring geometry proficiency developed by Van Shields has been widely recognized by the academic community, and many scholars have investigated the current state of students' intuitive geometry literacy based on it [3].

Studies have shown that junior high school students have different geometric intuition literacy. In a survey of first-year students' mathematical ability, Chen and others found that among the eight mathematical ability indicators, "spatial concepts" and "geometric intuition" scored lower, and the standard deviation values were larger, indicating that students' cognitive variability was also larger [4]. Xu and others investigated the level of students' geometric intuition literacy from the unit test papers and showed that students' levels of this literacy varied [5]. Liu and Wei [6] found that most students' development of "geometric intuition" met the requirements of the national curriculum standards, and there was no gender difference in the development of "geometric intuition" between male and female students [7]. Cui and others investigated the current situation of geometric intuition among middle school students in minority areas of Yunnan Province and found that middle school students' awareness and habits of representing problems with the help of graphs, understanding problems with the help of graphs, analyzing and solving problems with the help of graphs were still weak, and their ability to use geometric intuition should be further improved [2]. The results showed that the overall level of geometric intuition of eighth-grade students in China was average and there were significant differences in the performance of geometric intuition among students from different regions and different academic levels [8].

2.2 Strategies for Developing High School Students' Geometric Intuition Literacy

Textbooks are the main forum for developing geometric intuition literacy and have received a lot of attention from researchers, from the analysis of the content to the development of the

materials. Many contents in different mathematical domains involve geometric intuition. For example, Zhao and Wang analyzed some cases in the field of numbers and algebra in junior high school textbooks. Although many contents of "Number and Algebra" are abstract and non-intuitive, describing and representing the contents of Number and Algebra with the help of graphics can help students build up a visual image of the relevant contents in their minds and promote students' understanding of the inner connection between the relevant contents [9]. The design of instruction is an important part of teaching and learning. Instructional design is an important part of teaching and learning and is important for teachers to teach, while researchers have focused on this aspect of instructional design in developing geometric intuition literacy. Li specialized in exploring what basic requirements should be met for teaching middle school algebra based on geometric intuition design and summarized the methods and approaches for teaching design of geometric intuition in middle school algebra as mastering basic figures [10]. Zhou based on the basic requirements of each specific part of middle school mathematics teaching design, according to the specific situation, creates a variety of intuitive objects, enriches intuitive thinking, and other four specific teaching design strategies [11].

The cultivation of geometric intuition literacy eventually falls into daily teaching, and the teaching strategies concerned initially start with the analysis of specific cases, such as Huang's illustration of the application of geometric intuition in high school mathematics teaching to better utilize the positive effects of intuitiveness [12]. Jiang used a junior high school plane geometry classroom as an example to explore how geometry teaching in rural junior high schools should link geometric intuition with inspiring teaching. With the development of information technology, scholars have focused on the role of information technology in developing literacy [13]. Li [14], Hu [15], and Zhou [16] advocate the appropriate use of the convenient functions of modern computer technology in teaching to develop geometric intuition literacy, such as the Super Geometry Drawing Board, and even provide teaching cases that combine information technology with geometric intuition.

From the above analysis, it is found that scholars have made diversified pedagogical suggestions on the implementation of geometric intuition literacy mainly in terms of knowledge understanding, knowledge transfer, and knowledge innovation. For example, understanding of theorems and formulas; geometric intuition in algebra teaching; and geometric intuition development under the integration of information technology. However, for teaching implementation aspects, most of them are based on the results obtained from surveys and interviews and then failed to conduct actual teaching experiments to verify the appropriateness of the suggestions, only a few researchers have conducted experimental verification, for example, Wang conducted validation through experiments after proposing teaching strategies [17].

The degree of cognition generally includes cognitive accuracy, cognitive breadth, cognitive depth, and cognitive clarity. Therefore, the main questions studied in this paper are:

1) How accurately do current pre-service junior high school school mathematics teachers comprehend geometric intuition literacy?
2) How widely do current pre-service junior high school school mathematics teachers comprehend geometric intuition literacy?
3) How deeply do current pre-service junior high school school mathematics teachers comprehend geometric intuition literacy?
4) How clearly do current pre-service junior high school school mathematics teachers comprehend geometric intuition literacy?

The current study suggests that the current level of geometric intuition literacy among middle school students are low and that teachers' knowledge of geometric intuition literacy is an important factor affecting students' geometric intuition literacy. Therefore, the hypotheses of this study are:

Hypothesis 1: Current pre-service junior high school school mathematics teachers' perceive accuracy of geometric intuition literacy is low;

Hypothesis 2: Current pre-service junior high school school mathematics teachers do not have a broad range of knowledge about geometric intuition literacy;

Hypothesis 3: Current pre-service junior high school school mathematics teachers do not have a deep knowledge of geometric intuition literacy;

Hypothesis 4: Current pre-service junior high school school mathematics teachers have unclear perceptions of geometric intuition literacy.

3. THEORETICAL BASIS

There is a wealth of previous research on what geometric intuition literacy is, what its manifestations are, and what its values are.

Comenius and Pestalozzi advocate intuitionism and they believe that intuition is a direct insight into the nature of things without sufficient logical reasoning, that is, a direct grasp of the whole picture of an object. M. Klein believes that intuition in mathematics is a direct grasp of concepts and proofs [18]. In 2011, "The Curriculum Standards for Compulsory Education in Mathematics (2011 Edition)" proposed that in teaching, Teachers should initially establish students' spatial concept, so that students' visual thinking can be developed [19]. Based on the interpretation of geometric intuition in this standard, Kong and Shi believe that geometric intuition refers to the ability to directly perceive and grasp the object of study in mathematics as a whole with the help of the visual relations of geometric figures seen [20]. Cui and others explained geometric intuition as the ability to analyze, understand, and solve mathematical problems by essentially generating the perception of quantitative relationships and other essential properties of the object of study directly with the help of figures [2]. From a psychological perspective, Jiang believes that geometric intuition is a direct mental state of recognition or conjecture of the human brain about objective things and their relationships [21]. From the above discussion on the connotation of geometric intuition, it can be seen that although the concept of geometric intuition is rich and not easy to grasp, different researchers are more consistent in their understanding of the use of geometric figures to describe, analyze, and solve problems.

Subsequently, scholars have researched the manifestations and meaningful values of geometric intuition literacy. According to Kong and Shi, geometric intuition is manifested in four forms: physical intuition, simple symbolic intuition, graphical intuition, and substitution intuition [20]. Gu and Zhang analyzed middle school mathematics textbooks and found that the expressions of geometric intuition are intuitive representation, intuitive analysis, intuitive explanation, and intuitive discovery [22]. At present, most experts and scholars agree with Kong and Shi in their understanding of the presentation of geometric intuition. Ye and others study the value of geometric intuition from mathematics itself in conjunction with the specific mathematical content of junior high school. He believes that geometric intuition has a guiding, bridging, and catalytic role in mathematics [23]. Zhang explains the value of geometric intuition in terms of both graphics and thinking as numerical integration, geometric transformation, sympathetic reasoning, and abstract concrete [24]. Geng and Wu found the value of geometric intuition in their study of distance problems as it can help students understand mathematics intuitively and play an important role in the process of learning mathematics [25]. Geometric intuition has both epistemological and methodological values that not only allow students to learn mathematical content through it but also allow teachers to improve the effectiveness and quality of their teaching.

The Ministry of Education of the People's Republic of China has comprehensively summarized these ideas, and the most formal statement is given in the latest version of the Curriculum Standards for Compulsory Education in Mathematics (2022 Edition), which was issued in 2022. The new standards state that geometric intuition refers primarily to the awareness and habit of using diagrams to describe and analyze problems. The requirements for teaching geometric intuition are: to be able to perceive various geometric figures and their constituent elements, to classify them according to their characteristics; to draw corresponding figures according to verbal descriptions and to analyze their properties; to establish the connection between shapes and numbers and to construct intuitive models of mathematical problems; to use diagrams to analyze real situations and mathematical problems and to explore ideas for solving them. The standards also explain that the value of geometric intuition is that it helps to grasp the essence of a problem and clarify the path of thinking.

To ensure the objectivity of the study, the study used the definition of geometric intuition literacy in the Compulsory Education Mathematics Curriculum Standards (2022 Edition) to examine the extent to which pre-service middle school mathematics teachers perceive geometric intuition literacy.

4. RESEARCH METHODS

4.1 Sampling Method and Participants

To faithfully reflect the pre-service junior high school mathematics teachers' perceptions of geometric intuition literacy, we use stratified sampling and convenience sampling to select 40 mathematics education masters as research objects, among which 38 are female and 2 are male. These two sampling methods can be more convenient to select representative samples. Participants all hold mathematics teaching certificates and have the intention to go to junior high schools for future employment.

4.2 Instrument

To understand the real perceptions of pre-service junior high school mathematics teachers about geometric intuition literacy, this study adopted the open-ended interview method to investigate, and three questions were designed in the interview, such as "How do you understand geometric intuition literacy?". According to the evaluation of many experts, these problems have high validity and reliability, and are relatively reliable. The open-ended interview method was adopted because the conversation is flexible, which is conducive to in-depth investigation and obtaining deeper and more reliable information.

4.3 Data Collection Method

The study used open-ended interviews to interview each of the 40 pre-service teachers individually. All interviews lasted 400 minutes, about 10 minutes for each interviewee. The face-to-face interview was conducted and the audio was recorded with the consent of the interviewee. The interview was a one-time interview without follow-up interviews.

4.4 Data Processing Method

The content of the Curriculum Standards (2022 edition) regarding geometric intuition literacy was first divided and coded, using A, B, and C to denote the meaning of geometric intuition, the requirements in the standards, and the significance. This resulted in a total of 3 areas of A-C and 6 items of A1 - C1, which are shown in Table 1. The content of the recorded interviews was then converted into text, and, except for intonation words such as um, ah, and uh, was organized strictly according to the original words spoken during the interviews, and compared with the coded. The content of the interview was compared with the coded content one by one, and if the content had similar meaning, the respondents were considered to be able to recognize it, and the level of awareness was additionally determined based on the completeness and accuracy of the respondents' expressions. Through coding, scattered interview quotes are quantified, which is convenient for follow-up research and quantitative qualitative research. Two researchers independently coded the results of the interviews and classified the accuracy and clarity to ensure the reliability of the study. Finally, the number of people who mentioned each item was counted, and the corresponding percentage was calculated to make a statistical table.

Table 1. Content coding of geometric intuition literacy

Category	Label	Content
A Meaning	A1	Awareness and habit of using diagrams to describe and analyze problems.
B standard requirements	B1	Be able to perceive various geometric figures and their constituent elements and classify them according to their characteristics.
	B2	Draw the corresponding graph according to the verbal description and analyze the properties of the graph.
	B3	Establish the connection between shapes and numbers and construct visual models of mathematical problems.
	B4	Use diagrams to analyze real-world situations and mathematical problems and explore ideas for solving them.
C Meaningful value	C1	Geometric intuition helps to grasp the essence of the problem and clarify the path of thinking.

5. RESULTS

5.1 Cognitive Accuracy

In this study, the content related to geometric intuition literacy in the Curriculum Standards (2022 Edition) was divided into six items, including one meaning, four requirements in the curriculum standards, and one meaningful value, among which the most people could recognize the meaning of geometric intuition literacy, 26 people (65% of the total number), while 20 people (50% of the total number) could recognize the meaning of geometric intuition literacy accurately; No one could recognize the fourth item of the standard requirement, "Use diagrams to analyze actual situations and mathematical problems and explore ideas for solving problems", and only two people could recognize the first and third items of the standard requirement accurately, accounting for 5% of the total number of students, as shown in Table 2.

It can be seen that the number of pre-service junior high school mathematics teachers' cognition of general content such as meaning is high, and the accuracy is half; for open content such as meaning, the number of cognition is half, but the number of those who can cognize accurately is very small, which means that pre-service teachers cannot cognize the value of geometric intuition literacy accurately, but can only talk about their ideas in general; for the cognition of the requirements of geometric intuition literacy in the curriculum The number of teachers who knew the requirements of geometric intuition literacy in the curriculum was low, and the degree of accuracy was the lowest.

5.2 Cognitive Breadth

Of the six items related to geometric intuition literacy, pre-service middle school mathematics teachers were able to recognize five of them, accounting for 83.33% of the total points. Among them, the largest number of teachers could recognize the meaning of geometric intuition literacy as "the awareness and habit of using diagrams to describe and analyze problems", 26 of them, accounting for 65% of the total number.

From different aspects, the "standard requirements" of geometric intuition literacy in middle school teaching are divided into 4 points, and the research subjects can recognize 3 points, accounting for 75% of the total points; the value of geometric intuition literacy is described in the curriculum standard as "geometric intuition helps to grasp the essence of problems and clarify the path of thinking "The study participants can recognize the value of geometric intuition in junior high school mathematics, and have many different views, as shown in Table 3.

From the above statistics, it can be seen that more than half of the current pre-service junior high school mathematics teachers know about geometric intuition literacy, but most of the research subjects' knowledge is focused on individual points, and the number of people who know the requirements of geometric intuition literacy in the curriculum standards is very small, and even individual requirements are not known. In terms of the specific content, the subjects had a higher level of awareness of the more general content of geometric intuition literacy, such as "meaning" and "significance," and a lower level of awareness of some details specified in the Curriculum Standards (2022 edition), such as The specific content of the "requirements of the standards".

5.3 Cognitive Depth

In this study, most of the 6 points related to the content of geometric intuition literacy, most of the study participants could only recognize 2 points or less, accounting for 82.5% of the total number of participants, and no one could recognize all 6 points. Moreover, the pre-service teachers' cognitive content was focused on the meaning and significance, and they did not know the requirements of the standards deeply.

Table 2. Statistics of recognition accuracy results

Category	Label	Number	Percentage	Accurate	Percentage
A Meaning	A1	26	65	20	50
B standard	B1	8	20	2	5
requirements	B2	3	7.5	0	0
	B3	9	22.5	2	5
	B4	0	0	0	0
C Meaningful value	C1	20	50	3	7.5

Table 3. Awareness breadth results in statistics

	A Meaning	B standard requirements	C Meaningful value
Cognitive Points	1	4	1
Total Points	1	3	1
Percentage	100	75	100

Table 4. Statistics of cognitive depth results

Recognizing points	Number of people	Percentage of total
0	8	20
1	11	27.5
2	14	35
3	2	5
4	3	7.5
5	2	5
6	0	0

Table 5. Statistics of cognitive clarity results

Category	Label	Clarity percentage (low degree: high degree)
A Meaning	A1	76.92: 23.08
B standard requirements	B1	25.00: 75.00
	B2	0.00: 100.00
	B3	22.22: 77.78
	B4	0.00: 0.00
C Meaningful value	C1	15.00: 85.00

It can be seen that current pre-service junior high school mathematics teachers have a deeper and more comprehensive understanding of the "meaning" of geometric intuition literacy and other general content, but a shallow and incomplete understanding of the details required in the curriculum. In general, the current pre-service middle school mathematics teachers have a low depth of knowledge about geometric intuition literacy, and most of them are not able to deeply understand geometric intuition literacy in the curriculum.

5.4 Cognitive Clarity

In this study, the cognitive level was determined based on the completeness and accuracy of the respondents' expressions, and the percentages of the total number of respondents with high and low cognitive levels were calculated separately. Through the survey statistics, it was found that the current pre-service middle school mathematics teachers were most aware of "the meaning of geometric intuition literacy", the number of people who were aware of it was high, and the percentage of cognitive clarity was 76.92:23.08. On the contrary, the pre-service teachers were aware of the requirement of geometric intuition literacy in the curriculum, the percentage of clarity of pre-service teachers' perception of the requirement of geometric intuition literacy in the curriculum "to be able to abstract physical geometric figures in familiar contexts" is 0.00:100.00, and only a few respondents can recognize it, but the clarity of their perception is extremely low.

As a result, the current pre-service middle school mathematics teachers have a clear understanding of geometric intuition literacy, and they mainly focus on the aspect of "meaning", while other points are either not recognized or are vague. On the whole, the current pre-service middle school mathematics teachers' perceptions of geometric intuition literacy are rather vague, as shown in Table 5.

6. DISCUSSION

6.1 Cognitive Accuracy

From the above analysis of the data, it is clear that the accuracy of current pre-service middle school mathematics teachers' cognition of geometric intuition literacy is low. Specifically, the number of pre-service teachers' cognition of

meanings was high and accurate, but most of the contents, such as the detailed requirements of the standards and the value of meanings, were not well recognized, could not be accurately expressed, and even individual points could not be cognized. Regarding this issue, Wei found through investigation that teachers' teaching style will affect students' geometric intuitive development, but teachers' understanding of geometric intuitive development is not accurate enough, resulting in poor geometric intuitive development of students [6]. It can be seen that pre-service junior high school mathematics teachers' cognitive accuracy of geometric intuition literacy is not high, and Hypothesis 1 was verified.

6.2 Cognitive Breadth

From the above analysis of the data, it can be seen that pre-service junior high school mathematics teachers' knowledge of geometric intuition literacy can be more than half of the range, but the knowledge of the study subjects is mostly focused on individual points, and the overall knowledge of geometric intuition literacy is not broad enough. As for the specific contents, the pre-service junior high school mathematics teachers' knowledge of geometric intuition literacy in the standards was focused on the general contents such as meanings, and their knowledge of the detailed contents such as the requirements of the standards was less, and even they did not know the individual requirements of the standards. On this issue, Zhao and Pan have found that many high school mathematics teachers are not high in mathematics discipline literacy [26]. It can be seen that preservice junior high school mathematics teachers' knowledge of geometric intuition literacy is not extensive, and hypothesis 2 was verified.

6.3 Cognitive Depth

From the analysis of the above data, it can be seen that the current pre-service middle school mathematics teachers have a deeper and more comprehensive understanding of the "meaning" of geometric intuition literacy and other general contents, while they have a shallow and incomplete understanding of the details required by the curriculum. On the whole, preservice junior high school mathematics teachers' knowledge of geometric intuition literacy is relatively superficial and mainly focused on the lower level. Regarding this issue, Tang found that most teachers only know that students should cultivate geometric intuition literacy and that geometric intuition literacy is the core literacy that students should possess, but they lack awareness of geometric intuitive literacy and have a low degree of understanding [27]. We can thus see that the overall depth of current pre-service junior high school mathematics teachers' knowledge of geometric intuition literacy is low, and Hypothesis 3 was verified.

6.4 Cognitive Clarity

From the analysis of the above data, it can be seen that the current pre-service junior high school mathematics teachers have a clear understanding of geometric intuition literacy in a few points, and mainly focus on the aspect of "meaning", while most of the other points are either not recognized or are rather vague. On the whole, current preservice junior high school mathematics teachers' perceptions of geometric intuition literacy are rather vague. With regard to this issue, Song found that teachers' understanding of geometric intuition is vague through case analysis and interview, and they could not clearly express the corresponding contents of geometric intuition [28]. We can see that the clarity of the current pre-service junior high school mathematics teachers' perceptions of geometric intuition literacy is low. Hypothesis 4 was verified.

7. CONCLUSION

Previous studies have shown that teachers' perceptions of geometric intuition literacy affect the development of junior high school students' geometric intuition literacy, and the current level of junior high school students' geometric intuition literacy is generally low, so is it that teachers' perceptions of geometric intuition literacy are not high? In this study, 40 pre-service junior high school mathematics teachers were selected as the research subjects, and open-ended interviews were used to investigate the pre-service junior high school mathematics teachers' perceptions of geometric intuition literacy. Through the interviews and analysis, we can find that: (1) The current pre-service junior high school mathematics teachers do not know geometric intuition literacy accurately and reasonably. (2) They do not know a wide range of geometric intuition literacy, and pre-service teachers' knowledge of geometric intuition literacy mainly focuses on the content with strong generalization. (3) The current pre-service junior

high school mathematics teachers have a shallow overall knowledge of geometric intuition literacy, mainly focusing on the lower level, while they know some of the content with strong generalization more deeply and comprehensively. (4) The overall cognitive clarity of geometric intuition literacy is low, with fewer points recognized and most other points either not recognized or vaguely recognized.

From the above analysis, it is recommended that: teacher education should pay attention to the curriculum education and learning of geometric intuition literacy for teacher trainees. In the training of pre-service teachers, special training and education on core literacy, especially geometric intuition literacy, should be strengthened so that geometric intuition literacy can be paid attention to. At the same time, pre-service junior high school mathematics teachers should actively study and research core literacy and improve their understanding of geometric intuition literacy to have a comprehensive understanding of the content of geometric intuition literacy, a study in depth the meaning of geometric intuition literacy, requirements, and other specific content in the curriculum.

The sample selected for this study was small and focused on the same grade level in the same institution, and did not cover other groups of pre-service junior high school mathematics teachers, so the sample selection was narrow. Therefore, in the future, it is necessary to expand the scope of the study sample and conduct more in-depth research on pre-service junior high school mathematics teachers' perceptions of geometric intuition literacy, using various research methods to find more detailed and comprehensive results.

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CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standard or university standard guideline participant consent and ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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