



# Research on Implementing the Core Literacy of Intuitive Imagination in Senior High School Mathematics Teaching

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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**

In the process of senior high school mathematics learning, improving students' intuitive imagination core literacy can enhance their ability to combine numbers and shapes. It also plays an important role in developing geometric intuition, spatial imagination, and understanding the essence of things. We first summarize the current strategies for cultivating the core literacy of intuitive imagination, then provide an overview of the intuitive imagination in core literacy. The author interviewed 12 senior high school mathematics teachers who were teaching locally in various cities in Shandong province with a large population and balanced education levels. Through interviews, it is learned that, students always lack numerical evidence when doing exercises, and most students only look at questions without sketching. During teaching, teachers closely follow the textbook but lack explanation of flexible problem-solving methods using geometry, and they may experience improper use of teaching aids or incoherent explanations. Finally, corresponding strategies are provided.

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## 1. INTRODUCTION

In the General Senior High School Mathematics Curriculum Standards (2017 Edition, 2020 Revision), six core competencies with cohesion are clearly proposed, including mathematical operations, mathematical abstraction, mathematical modeling, logical reasoning, intuitive imagination, and data analysis [1]. Among them, intuitive imagination is an important means of discovering and posing problems, analyzing and solving problems. It is also the thinking foundation for forming argumentative ideas and constructing abstract structures. The combination of numbers and shapes, as well as the ability of intuitive imagination, plays a significant role in helping students understand the essence of things. Therefore, how to implement the core literacy of intuitive imagination in senior high school mathematics teaching is a major task.

Currently, there are many studies on the cultivation strategies of intuitive imagination core literacy in China, and the vast majority of them expressed corresponding views through statistical analysis of questionnaire survey results or based on teaching in case classrooms. For example, Yunfei Hu thinks that we should not only attach importance to students' dominant position to mobilize their initiative, but also to the understanding and transformation between words, graphics and symbols, and their intuitive perception [2]. Xuejing Zheng, Qinghua Chen and others think that it is necessary to coordinate the development of intuitive imagination and logical reasoning, cultivate a higher level of intuitive imagination, pay attention to the relationship between intuitive imagination and other core literacy [3]. Xuefen Bei believes that it depends on the combination of numbers and shapes, with the help of mathematical model and information technology, innovative teaching methods [4]. Detong Xu and Yunxiang Qian think that it is necessary to strengthen the teaching of "drawing pictures according to the description of language" and study the cognitive law [5].

At present, these studies mainly proposed relatively comprehensive and relevant strategies for cultivating core competencies in intuitive imagination through questionnaire measurement results or classroom teaching characteristics. It has certain scientific basis, but less consideration is given to in-depth analysis of the connotation of

core competencies and conducting corresponding interviews. This paper will focus on the analysis of the definition, requirements and performance of the core literacy of intuitive imagination. Then through interviews with some in-service teachers combined with the more appropriate real experience and feelings of front-line teachers, corresponding strategies will be put forward.

## 2. INTUITIVELY IMAGINE THE CONNOTATION OF CORE LITERACY

### 2.1 Intuitively Imagine the Definition of Core Literacy

Intuitive imagination refers to the literacy of perceiving the shape and change of objects with geometric intuition and spatial imagination, understanding and solving mathematical problems with spatial forms, especially graphics. Geometric intuition refers to the ability to directly perceive and grasp the mathematical research object with the help of the image relationship of geometric images seen or imagined [6]. Spatial imagination refers to the reappearance and reconstruction of objective things in individual minds after mathematical abstraction [7]. Perception is the feeling and perception of things. The form and changes of an object refer to the size, shape, state, and changes that occur in these aspects of the object. Spatial form refers to the concrete manifestations of objects, such as two-dimensional graphics and three-dimensional geometry. Mathematical problems are problems related to mathematical knowledge.

Therefore, intuitive imagination refers to using geometric intuition and spatial imagination to feel the size, shape, state, and changes that occur in these aspects of things. The ability to utilize the specific forms of objects, especially two-dimensional graphics, to understand and solve mathematical knowledge related problems.

### 2.2 Intuitively Imagine the Content Requirements of Core Literacy

#### 2.2.1 Understand the positional relationship, morphological changes and motion laws of things with the help of spatial forms

Position relationship is a relative concept that encompasses a wide range of contents in

geometry, such as parallelism, intersection, perpendicularity, angles formed, distance in solid geometry. The law of motion refers to the law that an object follows in the process of motion, such as the central symmetrical figure rotates 180 around the center and coincides with the original figure. This requires students to use the specific forms of objects to understand the orientation, distance, size, shape, state, as well as their changes and changing relationships.

### **2.2.2 Using images to describe and analyze mathematical problems**

Description is to describe the problem vividly according to its characteristics. Analysis is to find out the essential attributes of the problem and the relationship between them. This requires students to fully understand the characteristics of images, be able to vividly depict mathematical problems and find out their essential attributes and relationships.

### **2.2.3 Establish the relationship between number and shape, build an intuitive model of mathematical problems, and explore ways to solve problems**

Number and shape refer to quantitative relationship and spatial form respectively. Intuitive model refers to a comprehensive approach that uses familiar and observable graphics to represent the relationship structure of a problem. It can concretize abstract theories, demonstrate dynamism and intuitiveness. Require students to connect through quantitative relationships and spatial forms, in order to construct a familiar and observable relationship structure for mathematical problems, so as to grasp the essence of problems and find solutions to them.

## **2.3 Intuitively Imagine the Performance of Core Literacy**

### **2.3.1 Establish the relationship between number and shape**

As the cornerstone of mathematical content, quantitative relationship and spatial form have a certain transformation relationship. Strengthening the relationship between numbers and shapes can, on the one hand, clarify some properties of geometry by using the accuracy of numbers, and on the other hand, reveal some relations of numbers by using the intuition of images. As Mr. Luogeng Hu said, it is less intuitive when the

number is missing, and it is difficult to be nuanced when the number is missing [8].

### **2.3.2 Using geometric images to describe problems**

Geometric image refers to the figure abstracted from the physical object. With the help of the relationship between numbers and shapes, many mathematical problems involving geometry can form corresponding images based on the given text and numbers, achieving a transformation from abstract to intuitive. Using geometric images to describe problems is also understood as using the visual relationships of geometric shapes to describe abstract and complex problems.

### **2.3.3 Understand the problem intuitively with geometry**

Explanatory notes of geometric intuition refer to the use of graphics to describe and analyze problems, and geometric images to describe problems. Utilize geometric intuition to perceive the quantitative relationships and spatial forms of research problems as a whole, in order to grasp the essential characteristics of the problem. Make complex mathematical problems vivid, explore solutions, predict results, and gain a profound understanding of the problem.

### **2.3.4 Understanding things by using spatial imagination**

Compared to geometric intuition, spatial imagination highlights the ability to imagine the shapes and relationships of shapes even without a certain background. In terms of content, it also emphasizes the understanding of the motion, variation, and positional relationships between two-dimensional and three-dimensional geometric shapes. Therefore, we can use spatial imagination to understand the position, shape and motion state of things.

## **3. THE ANALYSIS OF THE CURRENT SITUATION OF TEACHING**

In order to get a deeper understanding of the current learning and teaching situation of students and teachers in the core literacy of intuitive imagination, interviews were conducted with 12 senior high school mathematics teachers from various cities in Shandong province which has a large population and a relatively balanced education level. The interviewees were young

teachers on the front line, so the interview content was representative and authentic. These interviews were mainly to understand the problems existing in students' learning and the difficulties encountered by teachers in the teaching process.

The interview content was divided into four small questions, each of which was controlled within 3 minutes, and the logic was smooth. The interview was recorded and anonymous. The topics of the interview were as follows: (1) What do you think is the main reason that students make mistakes or can't answer intuitive imaginary math questions? Please elaborate. (2) Have you found any improper or error-prone habits in the process of observing students' classes or solving problems? If yes, please explain in detail. (3) What is the main basis for you to explain the content of intuitive imagination mathematics in class. Do you think it is enough? If not, what content should be strengthened? (4) Will there be a teaching jam when you explain the content in class? If so, what do you think is the main problem?

By listening to and recording the recordings of each answer of these 12 teachers many times, the common views of most teachers on each question were summarized, and the following status quo was obtained through sorting out and analyzing: Students sometimes rely on feelings to do problems, and lack of digital reasoning.

The vast majority of teachers have described that when many students answered some math problems with images, they would take for granted what they saw or thought as a fact without any reliable basis, and the final result was obtained under this unreasonable premise. In some geometry problems, the changes and transformations of images, as well as the addition of auxiliary lines, require students to expand their imagination and constantly try and make mistakes. However, the process of reasoning and proof must be based on the clear numbers in the question stem, following existing relevant theorems, and gradually deriving them step by step. Mathematics is a very rigorous subject. It is extremely unreasonable to jump to conclusions based on feelings and lack logic when solving problems.

### **3.1 Students will Only Watch and not Draw when Doing Class Activities or problems**

After interviews, many teachers talked about the phenomenon that many students just looked at

the topic with their eyes open and hung their hands aside during drawing or math problem-solving activities in class. Not to mention that there will be no way to start when solving more complicated topics, and even some simple topics will not be represented by drawing images, let alone talking about the steps of writing a standardized system. This "lazy behavior" of students who only look at pictures seriously affects the development of students' intuitive imagination ability. It also reduces students' ability to understand the nature of graphics and draw graphics skills. For mathematics, a subject that frequently uses graphics, it is important to be familiar with the properties of graphics and master the skills of drawing. The behavior of only looking at mathematical problems without drawing by hand is definitely opposed.

### **3.2 Teachers Stick to Textbooks in Teaching, but Seldom Explain how to Solve Problems Skillfully with the Help of Geometry**

About their teaching situation, most of teachers admitted that when told students about their knowledge, they mostly explained it according to the contents and examples in textbooks. There were relatively few expanded contents, especially the flexible use of various graphic skills. The phenomenon caused by this was that students would feel comfortable after listening to the teacher's lecture, and the examples in the textbook were easy to solve, but they found it more difficult to practice or test questions on the test paper. Students will be familiar with some questions that directly apply knowledge, and will be at a loss for some questions that are difficult to solve in a conventional way but can be expressed simply through geometric images. Not summarizing methods for flexibly applying images makes it difficult to improve students' mathematical problem-solving ability. Mathematics is a subject to test students' thinking ability and imagination abilities. The flexible application of geometry in the development of students' abilities cannot be ignored, although the explanation of basic knowledge is also important.

### **3.3 Teachers May not use Proper Models or Lack Coherent Explanations in Geometry Teaching**

It is learned from the interview that many teachers sometimes use models that students do

not understand very well and this fail to organize properly cohesive terms or sentences in explaining the evolution of new objects in geometry teaching. When students face unfamiliar objects, their thoughts are ever-changing. Everyone has his or her own life experience, and there is no relatively uniform standard at all. In the process, a new concept of objects suddenly pops up for students, which makes students unable to grasp the specific shape, size and position relationship of objects, not to mention their important characteristics. No matter how good the students' spatial imagination is, they can not have a clear representation of the graphics, understand the position relationship and motion state of the graphics. Therefore, it is not advisable for middle school teachers to use inappropriate models or lack coherent explanations in geometry teaching.

#### **4. STRATEGIES FOR IMPROVING CORE LITERACY IN INTUITIVE IMAGINATION**

##### **4.1 Emphasis is Placed on Solving Mathematical Problems by Combining the Numbers in the Conditions with the Given Figures**

In view of the thinking used by students in solving problems, teachers should teach students to pay attention to combine the numbers in the questions with the given figures, rather than responding paradoxically by feeling. The graphics given in the question provide a framework, which is only used as a reference. If it looks like it, it may lack mathematical rigor. Pay attention to combine the numbers given in the image and conditions when explaining the problem ideas. Using images as a reference, starting from numerical calculations, following geometric theorems to calculate corresponding quantities to provide clear evidence, and finally determining the position and interrelationships of objects. For example, to solve the positional relationship between two faces in a cube, a spatial coordinate system can be established to obtain the normal vectors of these two faces. By calculating the positional relationship between these two normal vectors, the positional relationship between the two faces can be inferred. This not only helps to strengthen students' thinking of combining numbers with shapes but also enables students to realize the close relationship between numbers and shapes.

##### **4.2 Cultivate and Encourage Students to Draw Corresponding Images When Solving Mathematical Problems**

For the phenomenon that students only look at the problems but don't draw, teachers should focus on cultivating and encouraging students to draw pictures to solve problems in classroom teaching. If students only look at the pictures but don't draw them, they just stay in the understanding of abstract numbers and have no understanding of the geometric content contained in them. When explaining example problems in class, demonstrate a clear drawing process and strictly require students to practice it to cultivate the habit of drawing. When solving problems after class, students should be encouraged to try drawing pictures to describe the problem. For example, in the profit problem, a quadratic function is listed based on the relationship between the given selling price and the sold items. Based on this, a graph of the quadratic function can be drawn to describe the basic situation of the problem through the graph. It can not only strengthen students' understanding of images but also to improve students' use of geometric images to describe problems.

##### **4.3 Pay Attention to the Induction and Summary of the Idea of Using Graphics to Analyze Problems**

In view of the fact that most teachers explain the examples and exercises of textbooks in class, teachers should pay attention to summing up and summarizing the skills and ideas on how to analyze problems with graphics. Although students have a solid grasp of the basic knowledge in textbooks, they will not be able to think of ideas for a while when they encounter comprehensive or transformational topics. Sometimes even rack their brains to think fruitlessly. At this point, the teacher needs to summarize some key and similar questions, and summarize the corresponding ideas for using graphics to analyze problems. When explaining exercises, focus on analyzing methods to help students master certain problem-solving skills while familiarizing themselves with basic knowledge. Students will also be able to handle similar or even innovative problems with ease. For example, when solving the inequality problem of a quadratic equation, we can draw its image, and then use the information such as the intersection of the image and the X-axis to

analyze the inequality, that is, the value range of the root, which makes the problem easy to understand [9]. This can not only strengthen students' ability to describe and analyze problems with images but also explore ideas, predict results and deeply understand problems.

#### 4.4 Use the Familiar and Characteristic Teaching Model to Explain Step by Step

Teachers should make proper use of students' common and qualified teaching models in teaching, and follow students' cognitive rules in explaining step by step. If teachers do not use appropriate teaching models, it can lead to students not having a clear and systematic representation of shapes or geometric bodies, resulting in inconsistent understanding. Incomplete understanding makes it difficult to conduct lectures, and at the same time, it is even more challenging to do exercises. In fact, before students enter the classroom, they already have a n understanding of external things in their brains. In classroom teaching, teachers should choose daily necessities that students are familiar with as much as possible to reduce strangeness. At the same time, it is necessary to strictly meet the requirements and characteristics, do a good job in the evolution of knowledge, let students think layer by layer, and finally form a clear understanding of the shape, size, and position of objects. [10]. When explaining rectangles, diamonds and squares, we can make full use of the door frames, telescopic doors in our lives to help students better understand their characteristics and properties and form a clear representation. It can not only improve students' spatial imagination ability but also strengthen students' understanding of various attributes such as object motion states in the future.

#### 5. CONCLUSION

To sum up, the all-round development of students is the ultimate goal of education, and the cultivation of core literacy plays a key role in the all-round development of students. As an important content of core literacy, teachers should strengthen teaching research, carefully study the connotations, requirements, and expressions of intuitive imagination. It is even more important to emphasize that students should use a combination of numbers and shapes to solve problems, cultivate and encourage the habit of drawing, summarize the

idea of using graphics to analyze problems, and explain them step by step with appropriate mathematical models.

But at the same time, there are still many shortcomings. The questions about the core literacy of intuitive imagination are wide in scope and not precise enough. We can make more targeted analysis of the specific chapters of high school knowledge and give corresponding strategies. By the way, we hope to further explore the psychological mechanisms of students in drawing and not drawing when solving problems in future research. Therefore, it proposes strategies to improve students' core literacy of intuitive imagination and better problem-solving skills.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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