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Research on the Mathematical Reasoning Ability in Junior High Schools 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

Mathematical reasoning ability is one of the main manifestations of core literacy in junior high school in China. Recently, many scholars have studied it, however, there is no literature summarizing and combing this aspect. This paper collects relevant literature from the China National Knowledge Infrastructure database in the last ten years, and uses the literature research method to draw the following conclusions: (1) At present, the research of scholars mainly includes four aspects: structural elements, current situation research, influencing factors and training strategies of mathematical reasoning ability in junior high school; (2) The current research results are more in the three aspects of current situation research, influencing factors and training strategies, and less in structural elements; (3) The measurement and evaluation of probabilistic reasoning ability is a blank spot in current research; (4) More in-depth analysis and research on the relationship, influence degree and influence path of the influencing factors of mathematical reasoning ability is the blank point of current research; (5) In terms of training strategies, scholars have little deeper research on textbooks, teaching methods, teaching models and so on. Therefore, it is necessary to further study the structural elements of mathematical reasoning ability, the current

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situation of junior high school students' probability reasoning ability, the main influencing factors and influencing paths of junior high school students' mathematical reasoning ability, and the deeper training strategies, to enrich the research results of mathematical reasoning ability in junior high school.

Keywords: Junior high school; mathematical reasoning ability; current situation; influencing factors; training strategies.

1. INTRODUCTION

Compulsory Education Mathematics Curriculum Standards points out that mathematical reasoning ability refers to the ability to start from some facts and propositions and introduce other propositions or conclusions according to rules [1]. Reasoning ability is a major manifestation of core literacy in junior high school and an important mathematical ability. Junior high school is a critical period for the development of students' mathematical reasoning abilities. Therefore, studying mathematical reasoning ability in junior high school is necessary. In recent years, there have been many related studies on mathematical reasoning ability in junior high school, but there is no general research in this area. This paper intends to make a comprehensive summary of the previous research, and systematically summarizes the research results of various aspects of mathematical reasoning ability in the current junior high school stage, to help researchers grasp the characteristics and current situation of the current research. More importantly, finding out the shortcomings and gaps will promote scholars to conduct further in-depth research.

The main problems studied in this paper are:

(1) What are the results of the current research on mathematical reasoning ability in junior high school?
(2) What are the shortcomings and gaps in the current research on mathematical reasoning ability in junior high school?

2. METHODOLOGY

2.1 Literature Sources and Types

The literature collected in this paper comes from the CNKI (China National Knowledge Infrastructure) database, which approximately contains all the contents of Chinese journals. The CNKI database can ensure persuasion and reliability. Moreover, in order to fully study the research results of mathematical reasoning ability in junior high school, this paper collects journal literature, dissertations and conference literature over the past 10 years.

2.2 Data Collection

In this paper, "mathematical reasoning ability" and "mathematical logic reasoning" are used as search terms in CNKI, and "topic" is used as search conditions. A total of 433 articles are retrieved. This paper uses the following criteria to filter the articles: (1) The research topic is highly correlated with mathematical reasoning ability; (2) The research section is the middle school section;(3) The literature content is not repeated. Finally, 33 references are selected.

2.3 Data Analysis

This paper uses the literature research method to read the collected literature and analyzes the literature from the aspects of literature author type, research content and research results.

3. RESULTS

3.1 Literature Author Statistics

There are three types of authors in the current research, namely, university researchers, middle school teachers, and cooperative research. University researchers include university teachers and college students. Middle school teachers include middle school mathematics teachers and teaching researchers. Cooperative research includes cooperation between universities and middle schools, and cooperation between universities and research institutions. Among them, the most author types are university researchers, accounting for 65.79%, and the least author types are middle school teachers, accounting for 10.53%. Table 1 for details.

3.2 The Structural Elements of Mathematical Reasoning Ability

In the study of the structural elements of mathematical reasoning ability, Wu [2] analyzed the structural elements of reasoning ability

through theoretical speculation, from the five different levels of reasoning in the process of problem-solving, namely, effectiveness, clarity and organization, flexibility, creativity, and introspection.

Table 1. Literature author statistics

Type of authors	Number	Percentage
University researchers	25	65.79%
Middle school teachers	9	23.68%
Cooperative research	4	10.53%

3.3 Research Status

At present, the research on the current situation of mathematical reasoning ability mainly focuses on the evaluation of reasoning ability and the existing problems.

3.3.1 Evaluation of reasoning ability

According to different standards, reasoning ability can be divided into different types.

According to the different forms of reasoning, reasoning ability can be divided into plausible reasoning ability and deductive reasoning ability. The former includes analogical reasoning ability and inductive reasoning ability. And according to the specific mathematical content, reasoning ability can be divided into algebraic reasoning ability, geometric reasoning ability, and probabilistic reasoning ability.

In the evaluation of mathematical reasoning ability, Wu divided its level. He proposed six-level requirements for mathematical reasoning ability in combination with the *Curriculum and Standards Framework* of Victoria, Australia [2]. Some researchers compiled the test questions of logical reasoning of junior high school students and revised them. The test questions include five dimensions: simple reasoning, disjunctive reasoning, propositional calculus, hypothetical reasoning, and plausible reasoning, and have good structural validity and reliability [3]. Moreover, some researchers have obtained the evaluation results. They pointed out that junior high school students' logical reasoning ability was at a medium level [4]. Chen et. al pointed out that the logical reasoning ability of junior high school students was at the upper middle level [5-8]. Among them, Wang [9] found that junior high school students had the strongest simple reasoning and the weakest disjunctive reasoning. According to Lan [10], the reasoning ability of grade 8 students was relatively good, but there was a serious polarization phenomenon. Yang [11] pointed out that junior high school students' mathematical logic reasoning ability was generally at a good level, and deductive reasoning was better than plausible reasoning.

On the evaluation of mathematical plausible reasoning ability, Song [12] formulated the evaluation framework and obtained the evaluation results. The evaluation framework contained three dimensions, namely, structure, content, and level. She pointed out that the overall level of plausible reasoning of grade 8 students was at level three, which was above the middle level; the plausible reasoning ability was better in the number and algebra part than the geometry and graphics part; students' inductive reasoning ability was better than analogical reasoning ability [12].

In the evaluation of mathematical analogical reasoning ability, Zhang divided analogical reasoning into five forms: nature analogy, relationship analogy, structure analogy, method analogy, and proposition analogy by literature method. Through the questionnaire survey, she believed that the reasoning ability of the third-grade students in the nature analogy was the highest, and the reasoning ability of other forms was not high [13].

In the evaluation of mathematical inductive reasoning ability, according to Han [14], the mathematical inductive reasoning ability of grade 9 students was generally at level two, medium level, and reached level two in the fields of numbers and algebra, graphics and geometry, statistics, and probability.

In the evaluation of mathematical deductive reasoning ability, Hao [15] constructed the evaluation framework of mathematical deductive reasoning ability from four dimensions: reasoning form, cognitive level, reasoning situation, and reasoning content through the literature method and expert evaluation method.

In the evaluation of algebraic reasoning ability, Han examined the algebraic reasoning ability of junior high school students from four aspects: generalization, characterization, calculation, and demonstration through a questionnaire survey. The conclusions are as follows: (1) Junior high school students were good at solving algebraic reasoning problems in a familiar knowledge

background; (2) In terms of generalization, most students were good at finding quantitative relations, but it was difficult to describe them in words; (3) In terms of characterization, the performance of transformation characterization was better, and the ability to generate characterization was poor; (4) In terms of calculation, most students could skillfully use equations to calculate, but the test consciousness was poor; (5) In terms of argumentation, most students could provide reasonable argumentation, but lacked logic [16].

On the evaluation of geometric reasoning ability, Li [17] summed up four geometric reasoning methods: intuitive, description, relationship, and formal logic. Moreover, she pointed out that the reasoning ability of junior high school students in these four reasoning methods showed a hierarchical progressive development trend, showed obvious differences in different reasoning methods [17].

3.3.2 Problems in reasoning ability

The current research mainly points out the problems of teaching materials, students, and teachers.

According to Wang [18], he conducted a quantitative study on the relevant content of inductive reasoning ability in the junior high school mathematics textbooks of the Beijing Normal University edition and the 2013 edition of the People's Education Press. It was found that the content of inductive reasoning ability in the two editions of the textbooks did not meet the requirements of the curriculum standards. Through investigation and analysis, it was found that teachers and students did not have a clear understanding of inductive reasoning. Teachers didn't know how to operate teaching, and some teachers and students had relatively weak inductive reasoning abilities [18].

Some researchers found that mathematical reasoning difficulties became the most important type of learning difficulty faced by junior high school students, and the degree of difficulty among boys was higher than that of girls [19]. Song [12] pointed out that students had problems such as weak reasoning consciousness, weak ability to extract information and poor reasoning habits when solving problems.

There were some problems in teachers' teaching, such as the weak ability to cultivate students' plausible reasoning, the weak ability to mine teaching materials and materials, and difficulty in combining plausible reasoning with classroom teaching [12].

3.4 Influencing Factors

According to the way that researchers get the influencing factors, the current research can be divided into three categories, namely, research based on influencing factors, difference analysis, and correlation analysis.

3.4.1 Research based on influencing factors of reasoning ability

In terms of mathematical reasoning ability, Lan [10] obtained through interviews that the direct factors affecting the mathematical reasoning ability of grade 8 students were mathematical reading, knowledge base, thinking mode, level requirements, other mathematical core literacy and ability, and reflection level. The indirect factors included students' psychological process (cognitive process, emotional process, will process), personality psychology (ability, interest, personality, habits, etc.), school and class teaching resources, teachers, and classroom atmosphere in terms of student groups. According to Wang [9], the development of junior high school students' logical reasoning ability depended on the mastery of reasoning rules and the understanding of mathematical knowledge.

In terms of mathematical inductive reasoning ability, Han [16] believed that the main factors affecting the mathematical inductive reasoning ability of grade 9 students were teachers and students. The factors of teachers included the lack of understanding of the importance of inductive reasoning, the lack of attention to the content of teaching materials, the lack of flexibility in teaching methods, and the lack of awareness of the application of mathematical inductive reasoning. The factors of students included interest in mathematics learning, cognition of mathematical inductive reasoning, bad habits of mathematics learning, and inflexible mathematical thinking in the process of reasoning [16].

3.4.2 Difference analysis

At present, the analysis of the differences in reasoning ability mainly focuses on gender, region, school, grade, and academic performance.

In terms of gender, most studies believe that there is no significant difference in reasoning ability between genders. Zhou et al. pointed out that there was no significant difference in the mathematical reasoning ability of junior high school students in gender [4,10,20-22]. B. L. Han [16] pointed out that there was no significant gender difference in the algebraic reasoning ability of junior high school students. Q. Han [14] thought that there was no significant gender difference in the mathematical inductive reasoning ability of grade 9 students. However, a few studies have also pointed out that there were significant gender differences in reasoning ability. Lan [10] found that there were significant gender differences in the mathematical reasoning ability of grade 8 students, and boys performed better than girls. Hao [15] found that there were significant gender differences in the deductive reasoning ability of grade 8 students, and girls performed better than boys.

In terms of regions, there are significant differences in mathematical reasoning ability among different regions. Some scholars pointed out that there were significant differences in the reasoning ability between urban and rural areas [4,21]. Moreover, the performance of the mathematical deductive reasoning ability of grade 8 students was significantly different between urban and rural areas, and urban students performed better than county and rural students [15]. According to Qi and Wang [23], British students scored higher than Chinese students in algebraic reasoning and probabilistic reasoning, and Chinese students scored higher than British students in geometric reasoning.

In terms of schools, there were significant differences in the logical reasoning ability of junior high school students between key schools and ordinary schools, and the logical reasoning ability of students in key middle schools was better than that of ordinary middle schools [22]. X. B. Zhou [4] believed that the performance level of logical reasoning of grade 8 students in private schools was better than that in public schools.

In terms of grades, Y. J. Zhou [21] thought that the deductive reasoning skills of junior high school students were significantly affected by grades.

In terms of academic performance, there were significant differences in the academic performance of mathematical reasoning ability of students in grade 8, and the better the academic performance, the higher the level of reasoning ability of students.

3.4.3 Correlation analysis

At present, the relevant analysis of reasoning ability mainly focuses on the cognitive structure, academic performance, ability, and emotional attitude.

Chen [5] studied the correlation between junior high school students' mathematical cognitive structure and logical reasoning ability. He found that they were significantly positively correlated and moderately correlated. The mathematical cognitive structure had a significant predictive effect on logical reasoning ability [5].

In terms of academic performance, the plausible reasoning ability of grade 8 students was positively correlated with their academic performance [12]. Additionally, there was a great correlation between the ability of mathematical inductive reasoning and the level of students' learning [14].

In terms of ability, many researchers have studied the relationship between logical reasoning ability and mathematical ability. According to Pu [20], there was a significant positive correlation between junior high school students' logical reasoning and their ability to solve open mathematical problems. Yang [11] found that there was a significant positive correlation between junior high school students' mathematical logic reasoning ability and mathematical problem-posing ability, and the correlation was mild. X. Y. Chen [6] pointed out that there was a significant positive correlation between logical reasoning ability and the ability to solve mathematical situation problems, and the correlation was moderate. The logical reasoning ability had certain predictive guiding significance for the ability to solve mathematical situation problems [6].

In terms of emotional attitude, Lu got many results. She found that the logical reasoning ability of junior high school students was significantly positively correlated with mathematics learning attitude, and significantly positively correlated with learning motivation, learning belief, and learning strategy dimension; mathematics learning attitude could positively affect logical reasoning ability, and its sub-dimension explanatory power from large to small was: learning belief, learning strategy, learning

motivation; among them, internal motivation, self-belief, process belief, knowledge belief, cognitive strategy, and metacognitive strategy had a significant impact on logical reasoning ability, while external motivation had no significant impact [7]. In addition, the plausible reasoning ability of students in grade 8 was positively correlated with their interest in learning [12]. Cao [24] pointed out that there was a significant negative correlation between junior high school students' mathematical reasoning ability and mathematical anxiety. Mathematical reasoning ability helped to reasonably predict and intervene in mathematical anxiety.

3.5 Training Strategy

At present, the research on the cultivation strategy of mathematical reasoning ability mainly focuses on the cultivation strategy of different types of reasoning ability.

The research on the overall mathematical reasoning ability training strategy mainly focuses on two aspects: teaching method and teaching process. Researchers have given more comprehensive training suggestions in these two aspects. In terms of teaching methods, inquiry teaching played a prominent role in cultivating junior high school students' mathematical reasoning ability, and it had more significant advantages than transfer-acceptance teaching [25]. Through theoretical speculation, Wang [26] concluded that mathematical experiments could provide rich problem situations for students' mathematical learning, let students experience the complete reasoning process of plausible reasoning to find conclusions and deductive reasoning to prove conclusions, and promote the formation and improvement of logical reasoning ability in the complementary of plausible reasoning and deductive reasoning.

In terms of teaching the process, Huang [27] put forward suggestions on cultivating students' mathematical reasoning ability from seven aspects through the experience summary method, which was: (1) Stimulating students' interest in mathematics learning; (2) Clear the importance of reasoning argument; (3) Pay attention to the stage of reasoning ability training; (4) Pay attention to the comparison and induction of knowledge; (5) Pay attention to the demonstration of teachers; (6) Inspiring students to think actively in teaching and fully mobilizing students' subjective initiative; (7) When correcting homework, pay attention to the correctness of students' reasoning and argumentation. Liu, Guo, Qin, and Quan proposed strategies to cultivate junior high school students' mathematical reasoning ability by creating situations [28-31]. In addition, Liu and Wang [28] emphasized that the creation of problem situations should be conducive to students' experience and feelings of the whole process of inductive reasoning and deductive reasoning, and the presentation of problems should ensure inquiry and scientificity. Guo [29] believed that teachers can use mind mapping to deepen students' thinking logic in teaching, they can also cultivate students' logical reasoning ability by constructing an integrated dynamic of teaching and learning to guide students to think gradually. Qin [30] proposed that students' reasoning literacy can be enhanced by implementing group cooperation. Quan [31] put forward specific training suggestions from three aspects: grasping key knowledge and paying attention to the combination of theory and practice. Wang [8] obtained seven training measures through the experience summary method: (1) Scientific and rational use of the combination of numbers and shapes; (2) Reasonably and effectively carrying out relevant practical activities; (3) Reasoning training, cultivating thinking consciousness; (4) Guide all students to draw pictures to solve problems; (5) Conduct group cooperative learning; (6) change students' learning psychology; (7) Create a democratic and harmonious atmosphere. Lan [10] also put forward training suggestions from the school and class level: (1) Schools should make full use of existing teaching resources and constantly tap new teaching resources; (2) Train teachers, improve teachers, and create a good learning atmosphere.

In the aspect of plausible reasoning ability, Li [32] put forward the hierarchical development framework of geometry curriculum improvement and its teaching design ideas through theoretical thinking. Liu [33] put forward four strategies to cultivate junior high school students' plausible reasoning ability: (1) Cultivate plausible reasoning ability with the help of a familiar teaching environment; (2) The ability to promote training in space and graphics learning; (3) Cultivate students' plausible reasoning ability through statistical probability; (4) Improve students' plausible reasoning ability in teaching problems. Yi [34] also proposed strategies to cultivate students' plausible reasoning ability from five aspects: number and algebra, space and graphics, statistics and probability,

mathematics concept learning, and a combination of students' living environments. Song [12] also pointed out the following five training teaching suggestions: (1) Create problem situations and encourage students to make more guesses; (2) Consolidate the foundation and build a plausible reasoning knowledge framework; (3) Variant practice, repeatedly strengthen the reasoning ability; (4) Improve the awareness of reasoning, focusing on independent reasoning; (5) Change learning methods and develop good reasoning habits.

In terms of analogical reasoning ability, Zhang put forward three suggestions for teachers, students, and evaluation systems. Suggestions for teachers were: (1) Explain the concept of analogical reasoning in teaching so that students can initially understand and learn; (2) Set the situation to stimulate students' interest in learning; (3) Solid foundation, find out the relationship between knowledge; (4) Strengthen students' understanding of analogical reasoning through textbook examples; (5) Strengthen training analogy exercises; (6) Experience summary, form the correct problem-solving ideas; (7) Repeatedly strengthen and improve students' analogical reasoning ability. Suggestions for students are: (1) Change learning methods and develop good learning habits; (2) Improve the ability of autonomous learning, promote the improvement of analogical reasoning ability; (3) Learn to read, listen, think, remember, and review. And the evaluation system should be diversified in evaluation criteria, evaluation contents, and evaluation subjects. [13].

In terms of inductive reasoning ability, Q. Han [14] put forward training strategies from both teachers and students. In terms of teachers: (1) Improve teachers' mathematical literacy; (2) Excavate the content of the textbook, deepen the understanding of inductive reasoning, and consciously infiltrate inductive reasoning into the classroom; (3) Pay attention to the creation of problem situations and cultivate students' mathematical inductive reasoning ability in situational teaching. In terms of students: (1) Deepen the understanding of inductive reasoning; (1) Standardize the problem-solving process; (3) In the learning process to establish confidence in learning, improve the interest in learning mathematics; (4) Develop good study habits in the learning process [16].

In terms of algebraic reasoning ability, B. L. Han [16] gave four teaching suggestions: (1) Give students more opportunities to describe the quantitative relationship in language and help students deepen their understanding of the quantitative relationship; (2) Pay attention to the teaching of representation and help students master a variety of representation methods; (3) Cultivate students' awareness of testing and help students develop the habit of testing; (4) Focus on students who have difficulties in developing algebraic reasoning ability.

4. DISCUSSION

Through the retrieval and analysis of the above literature, it can be found that scholars have carried out different aspects and different degrees of research on mathematical reasoning ability in junior high school.

In terms of the types of literature authors, at present, university researchers and middle school teachers are the two main types of authors, and the results of independent research are more, and the results of cooperative research are less. It can be seen from the research methods used by researchers that questionnaire surveys and statistical analysis are used most, and quantitative research methods are used more than qualitative research methods.

Furthermore, researchers in colleges and universities mostly use a combination of quantitative research methods and qualitative research methods to investigate and analyze the current situation of reasoning ability. Then, they give targeted training suggestions. Middle school teachers mostly adopt qualitative research methods, combine their teaching practice and experience, then propose training strategies. These two research methods have effectively promoted the research and development of reasoning ability, but there are also shortcomings. For example, the training suggestions proposed by university researchers may not be realistic, and some suggestions are of low practicability. The experience summary of middle school teachers sometimes lacks theoretical guidance, some strategies are one-sided and the promotion is not strong.

In terms of structural elements, only Wu Hong scholars analyzed the structural elements of reasoning ability through theoretical speculation. Therefore, there are few research results on structural elements.

In terms of current research, the current research mainly focuses on the evaluation and existing problems of reasoning ability, and the research

results are rich. However, there is also a lack of research on probabilistic reasoning ability. The research degree of probabilistic reasoning ability is lower than that of algebraic reasoning ability and geometric reasoning ability.

In terms of influencing factors, the current research has rich results in difference analysis and correlation analysis, and the influencing factors are more comprehensive. However, more in-depth analysis and research on the relationship between the various factors of mathematical reasoning ability, the degree of influence, and the path of influence have not yet been involved by scholars.

In terms of training strategies, scholars' research, on the whole, involves three aspects: schools, teachers, and students, and the suggestions and strategies given are also more comprehensive. However, there are few scholars involved in deeper research on teaching materials, teaching methods, teaching models, and so on.

5. CONCLUSION

Through the collation and analysis of the relevant literature on mathematical reasoning ability in junior high school, the following conclusions are drawn:

At present, scholars' research on mathematical reasoning ability in junior high school mainly includes four aspects, namely, the structural elements, current research, influencing factors, and training strategies of mathematical reasoning ability in junior high school. Scholars have rich research results in the three aspects of current situation research, influencing factors, and training strategies, and fewer research results in structural elements.

In the current research, the measurement and evaluation of probabilistic reasoning ability is the blank point of current research. In terms of influencing factors, more in-depth analysis and research on the relationship between the various factors of mathematical reasoning ability, the degree of influence, and the path of influence are the gaps in the current research. In terms of training strategies, scholars have little deeper research on textbooks, teaching methods, teaching models, and so on.

Therefore, it is necessary to study the structural elements of mathematical reasoning ability, analyze the current situation of probability reasoning ability of junior high school students, analyze the main influencing factors of mathematical reasoning ability and their influencing paths, and explore deeper training strategies such as teaching materials, teaching methods, and teaching modes, to promote scholars to conduct further in-depth research and enrich the research results of mathematical reasoning ability in junior high school.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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