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International Interventions to Promote Reasoning Skills in Primary and Secondary Schools and Their Implications for China

Siduo Zhang

Sichuan Normal University, No. 5 Jing'an Road, Jinjiang District, Chengdu

360463030@qq.com

Abstract. This article is written based on the lack of experimental interventions on various reasoning skills among primary and secondary school students in China. By comparing the content related to reasoning skills on the China National Knowledge Infrastructure (CNKI) with that from foreign sources, it is evident that research on intervention measures is more extensive internationally. Therefore, this article mainly focuses on searching for international interventions for reasoning skills in primary and secondary students, summarizing the main ideas and methods of these foreign measures to provide a theoretical basis for interventions in China. The article discusses the current state of research on reasoning skills in China and existing problems, defines reasoning skills based on curriculum standards, and includes definitions of subcategories by numerous researchers, including logical reasoning, deductive reasoning, inductive reasoning, analogical reasoning, and spatial reasoning. Regarding international intervention measures for reasoning skills, one or two typical examples are selected, and the research subjects, content of interventions, and results are organized. Considering China's national conditions, the article concludes with some measures and methods that could facilitate the development of reasoning skills among Chinese primary and secondary students.

Keywords: primary and secondary students, reasoning skills, intervention; subjectivity, core competencies

1. Introduction

1.1. Research Background

In the "Mathematics Curriculum Standards for Compulsory Education (2022 Edition)," an important element of mathematical core competencies—reasoning ability—is once again emphasized. It refers to the ability to infer other propositions or conclusions based on certain facts and propositions using rules. Reasoning ability, as a broad category, encompasses various subcategories such as logical reasoning, contextual reasoning, and spatial reasoning, each playing a different role in the learning of primary and secondary school students. The process of reasoning reflects a student's independent thinking as a learner, rather than passive learning. Therefore, mastering good reasoning skills can help primary and secondary school students develop a strong understanding and critical thinking ability in mathematics and other subjects, as well as enhance their language expression skills. However, the problems faced by Chinese primary and secondary school students in reasoning ability include uneven development of various reasoning abilities and teachers' lack of knowledge on how to intervene in students' reasoning ability development.

1.2. Research Background

Through searches on the China National Knowledge Infrastructure (CNKI), research in China on reasoning ability among primary and secondary school students can be categorized as follows: Firstly, through questionnaire surveys, testing of primary and secondary school students' reasoning abilities reveals that reasoning abilities are influenced by factors such as age, gender, emotions, classroom environment, and social environment, and there is uneven development among various reasoning abilities [1-3]. Additionally, only a small number of students are able to reach the "level three" stage proposed by scholars. Secondly, through interviews with teachers and students, it is found that some teachers face difficulties in teaching reasoning ability, and some students have incomplete understanding of reasoning ability [4-5]. Thirdly, scholars propose intervention measures based on the investigated situation, mainly emphasizing the establishment of problem scenarios and giving students the leading role in learning,

while teachers play a guiding role. However, there are still some issues in these studies: Firstly, the 2011 edition of the "Mathematics Curriculum Standards for Compulsory Education" only emphasized logical reasoning ability, which was elevated to "reasoning ability" in 2017. However, most researchers in China still focus on studying "logical reasoning ability," leading to a lack of research on other reasoning abilities. Secondly, most researchers only provide possible intervention measures by analyzing the current situation, and only a very few researchers conduct controlled experiments to explore the effectiveness of intervention measures, making it difficult to verify the actual effects of these proposed interventions. Therefore, this study focuses on intervention measures for various reasoning abilities, drawing on research from abroad where scholars not only study the "current situation" but also conduct research on "intervention measures." Many of these studies have demonstrated effective intervention measures and have been tested in practice, promoting the development of teachers' teaching and students' reasoning abilities. Some of these intervention measures have not been implemented domestically, hence providing insights into intervention measures for reasoning abilities among Chinese primary and secondary school students.

2. Research Significance

This study responds to the focus on reasoning ability within the core competencies of mathematics as highlighted in the "Mathematics Curriculum Standards for Compulsory Education (2022 Edition)"—a key aspect of education currently emphasized in China. This research not only analyzes reasoning ability but also delves into its many subcategories, broadening the understanding of what constitutes reasoning ability. Moreover, it provides a reliable theoretical basis for measures to improve reasoning abilities in primary and secondary school students in China. This study can identify intervention measures that are beneficial for developing reasoning abilities in Chinese primary and secondary school students. From the student's perspective, it effectively cultivates various reasoning abilities in primary and secondary school students, laying a solid foundation for their future mathematics learning and fostering independent thinking, which reflects the students' active role in learning. It also strengthens students' ability to analyze and judge things in everyday life. From the teacher's perspective, it provides a theoretical basis for teachers who struggle to cultivate students' reasoning abilities and aids teachers in designing mathematics lesson plans.

2.1. Reasoning Ability

Reasoning ability can be divided into several different types, such as spatial reasoning, contextual reasoning, logical reasoning, and scientific reasoning, each applicable in different scenarios.

According to the "Mathematics Curriculum Standards for Compulsory Education (2022 Edition)," reasoning ability primarily involves deriving other propositions or conclusions from certain facts and propositions based on rules. It includes understanding the importance of logical reasoning in forming mathematical concepts, laws, theorems, and solving problems, mastering the basic forms and rules of reasoning, deducing general conclusions from specific results, understanding the structure of propositions and practicing them, exploring and articulating the process of argumentation, and developing habits of logical expression and communication. Reasoning ability helps gradually foster a habit of evidence-based and logical thinking, forming a realistic scientific attitude and a rational spirit.

2.1.1. Logical Reasoning Ability

There is no consensus yet; some scholars believe that this ability allows students to use appropriate thinking methods to conclude or solve practical problems when facing mathematical issues, while others interpret "logical reasoning ability" from both logical and psychological perspectives [6]. Logical reasoning can be divided into two categories: one is reasoning from specific to general, such as induction and analogy; the other is from general to specific, such as deduction. The concept of logical reasoning traces back to Aristotle's syllogistic reasoning. The concept of scientific reasoning ability is still debated, but most definitions are similar to those of logical reasoning.

2.1.2. Inductive Reasoning Ability

This is manifested in mathematical inductive reasoning activities, including the process of conjecturing from specific to general and the testing of those conjectures. Some studies suggest that the cognitive process of mathematical inductive reasoning often involves the formation and expansion of classes.

2.1.3. Analogical Reasoning Ability

This is the ability to infer that objects share other attributes based on their similarity or identity in some properties. It starts with the observation of individual phenomena, thus resembling inductive reasoning. However, it differs from induction as it does not proceed from specific to general but from specific to specific.

2.1.4. Deductive Reasoning Ability

Deductive reasoning ability is the capacity to derive specific propositions from general ones, where the premises and conclusions have a necessary connection. This is a form of necessary reasoning, with syllogistic reasoning being a fundamental form of deductive reasoning in mathematics.

2.1.5. Spatial Reasoning Ability

Visual-spatial reasoning ability refers to the capacity to represent mental imagery formed in the brain during the process of solving geometric problems, combining geometric intuition and spatial imagination. It includes two forms of abilities: recognizing and constructing views and using views to solve problems [7].

3. Research Methods

3.1. Literature Review Method

The literature review method involves researching, categorizing, and evaluating existing literature, documents, and journals to re-examine previous studies. This research involves an extensive review and synthesis of both domestic and international literature on interventions for reasoning abilities in primary and secondary school students. It focuses primarily on the current state of reasoning abilities among domestic youth and the intervention measures for reasoning abilities in primary and secondary school students abroad, including how experiments are designed and the results achieved. The summarization of these studies provides a theoretical basis for this research and offers possibilities for implementing interventions domestically.

3.2. Comparative Method

By comparing the current situations and measures at home and abroad, this method identifies intervention methods suitable for the reasoning abilities of Chinese primary and secondary school students. This approach considers whether proposals by domestic scholars have been implemented in similar cases abroad and analyzes the effectiveness of these interventions to determine if they can serve as references for intervening in the reasoning abilities of primary and secondary school students in China. It also examines the effects of foreign intervention measures that differ from those in China, assessing their relevance to Chinese conditions and their potential as referential practices.

4. International Interventions for Enhancing Reasoning Abilities

4.1. Interventions for Logical Reasoning Abilities

In a study known as "Concreteness Fading," participants consisted of seven high school seniors who were non-science majors. They were trained to transition from "enactive" expressions to "iconic" expressions, and finally to "symbolic" expressions, moving from concrete to abstract representations. Initially, students could naturally understand enactive expressions, such as "If it rains, then the streets will be wet." Teachers taught students to use Venn diagrams to help them understand these vivid statements. In subsequent classes, students were introduced to syllogisms and engaged in open-ended tasks where they were encouraged to visualize these logics on paper. Teachers also encouraged students to express their ideas through imagery or directly use symbolic expressions. During group activities, where students worked in pairs or trios, they were asked to explain and correct each other's reasoning. The study ultimately demonstrated that students were able to spontaneously use Venn diagrams to aid their understanding of logical phrases found in newspapers and magazines.

4.2. Interventions for Inductive Reasoning Abilities

In a training dubbed "Playful Fostering," 90 children aged 6 to 8 participated in the experimental group, undergoing 12 training sessions totaling 120 exercises, while a control group did not receive such training [8]. The training sessions were designed around engaging games and images that focused on exercising the children's abilities to discern similarities and differences for inductive reasoning. Pretests and posttests showed that the experimental group significantly outperformed the control group in the posttest scores.

Another intervention involved over 200 fifth and sixth graders who participated in a computer-based training group [9]. The intervention group underwent 120 computer-based training sessions. After each question, students immediately received feedback on whether they were correct or incorrect, along with additional support information if they answered incorrectly. They could attempt the question again, receiving further hints if necessary. Results from the study indicated that the posttest scores of the intervention group were significantly higher than those of the control group.

4.3. Interventions for Deductive Reasoning Abilities

In Lyn D. English's study, 80 adolescents aged 10 and 12 were subjects, investigating their implicit and explicit justifications for logical and non-logical syllogisms under four conditions [10]. Condition 1 served as the control group, where the examiner read out the questions and asked the children to respond with a yes or no and explain their reasoning. Condition 2 involved providing only response options, including the option "I don't know," based on Condition 1. Condition 3 provided only model construction prompts, assisting in constructing models and analyzing major and minor premises based on Condition 1. Condition 4 combined Conditions 2 and 3. Results showed that Conditions 2 and 4, with the inclusion of response options prompts, led to more children providing correct responses. Moreover, under Condition 4, children were able to provide more explicit justifications rather than implicit ones.

4.4. Interventions for Analogical Reasoning Abilities

In a controlled experiment employing graduated prompts and outcome feedback, participants consisted of students from three age groups (kindergarten, first grade, and second grade) [11]. They were tasked with projects related to analogical reasoning. In the outcome feedback group, students were directly informed of their errors if they answered incorrectly, provided with encouraging feedback, and allowed up to four attempts. In the graduated prompts group, students were asked to explain their answers if they were correct, and if incorrect, they received prompts that became more detailed step by step. After training in both groups, the posttest results showed that the graduated prompts group outperformed the outcome feedback group.

4.5. Interventions for Spatial Reasoning Abilities

In a foreign study utilizing a software application called "virtual makerspace," 340 students aged 10 to 13 spent one hour per week over ten weeks engaging in games, competitions, and challenges within the software [12]. The software enabled 3D rotation of objects, multi-angle viewing, and various game modes like maze walking and block building to foster skills such as mental rotation, spatial orientation, and spatial visualization. Pretest and posttest data collected through school assessments indicated an overall improvement in students' spatial reasoning abilities, with the most significant enhancement observed in mental rotation. However, the improvements in spatial orientation and spatial visualization were more moderate. Additionally, notable improvements were observed among students slightly below the average level, while those far below the average level showed minimal improvement, suggesting that these students may not have reached their "zone of proximal development."

5. Conclusion

Reasoning ability is considered by many scholars to involve "agency," meaning that students are the principal agents of this skill, required to think and discover on their own. This ability is not simply transmitted unilaterally in the classroom by teachers. Many foreign interventions regard students as primary agents, guiding them to think independently, thus subtly influencing their various reasoning skills. For elementary and middle school students, whose attention spans are still developing and who struggle to focus on one thing for extended periods, many interventions incorporate methods to help them concentrate, such as games and engaging teaching methods. Some interventions also involve forming discussion groups where students can clash their conclusions against those of their peers. Moreover, teachers play a primarily "prompting" role in the development of reasoning abilities, offering cues that can open up students' thoughts and keep their reasoning processes moving forward.

Considering foreign intervention measures and the context of classroom-based teaching in China, the cultivation of reasoning abilities in elementary and middle school students can begin within the regular classroom setting by emphasizing student agency. Students can be encouraged to discuss among themselves and to present their thoughts on the platform, with the teacher providing timely prompts or using situational teaching methods that allow students to immerse themselves in certain knowledge bases to address various syllogistic issues, such as pondering different propositions. For younger students, more interest-driven courses could be introduced that use games and fun teaching methods to stimulate their reasoning abilities, as exemplified by the "virtual makerspace" mentioned earlier. Additionally, assigning engaging homework that sparks reasoning in everyday situations can further enhance their ability to think logically.

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