

Constructive View of Mathematics Learning: Mind Map as an Effective Tool for Error Management in Elementary Mathematics Classroom

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Abstract. In China, a large number of studies have investigated the impact of error management on academic performance, but there are few studies using mind mapping as a tool for error management. The present study explores the practice between error management methods adopted by students and students' error management metacognition and math achievement. Participants were 300 Grade 5 and 6 students from three schools in Zhejiang, China. In this study, a error management metacognitive questionnaire is used to collect data. The questionnaire was divided into 7 dimensions: concept, attitude, behavior, strategy, motivation, communication and atmosphere. According to the score of the questionnaire, the 50 students with the highest score are classified as high group, and the 50 students with the lowest score are classified as low group. The results showed that the two groups of students had little difference in the two dimensions of concept and attitude, and the other five dimensions were significantly different. Among them, the learning strategy dimension has the biggest difference in results. The use of mind mapping can effectively help students internalize knowledge, actively complete the construction of knowledge system, and promote the learning communication among students.

Keywords: Error management, mind map, mathematics learning, primary school.

1. Introduction

Students will inevitably make mistakes in math learning. An increasing number of educators have begun to view students' incorrect problems as valuable instructional materials in recent years. In the 2022 edition of mathematics curriculum standards, it is proposed that students should pay attention to the general solution of exercises, and the induction and analysis of wrong problems through mind mapping is more conducive to students' accurate analysis of knowledge blind spots. Steuer, Brunn, and Dresel argue that students' motivation and learning can be promoted by classroom error climate [1]. Domestic scholar Sun also paid attention to Senior High Grade One students' mathematical error management ability and its correlation with mathematics achievement. What is more, most of the research focuses on junior or senior school students and lacks guidance on error sorting methods. Therefore, in this study, the mind map will act as an intermediate variable to show the effect of error sorting on mathematics academic achievement. 500 elementary school students in grades five and six from Zhejiang China were participants and they filled in the questionnaire based on Zhan's to explore the current situation and strategy of the management of these students' math wrong questions [2]. Correlation analysis and linear regression are utilized during the analysis.

2. Literature Review

The collation of wrong questions is a specific manifestation of students' self-reflection. In 1986, at ICME5, Kilpatrick's report put reflection at the center of discussion in mathematics education. He indicates that reflection is done from a superordinate point of view and that activities on the object level are viewed from a meta-perspective [3]. His point of view has initially established a connection between reflection and metacognition. Lyons and Zelazo argue that the evidence from various literatures on monitoring, executive function, and metacognition suggest that children's self-reflective awareness and the corresponding adjustment of behaviours improve children's ability to alter their

patterns of thought and action [4], which means children who are more self-reflective will pay more attention to their error management and will be less likely to repeat the consent error in the future. Chinese scholar Pang also declares that the better the student's achievement, the higher the level of mathematical error management [5]. In addition, this article also shows that different error sorting methods, such as multiple solutions of one question and concatenation of knowledge points will also affect students' academic level [5]. Therefore, scholars began to use metacognitive methods to explore the impact of students' learning strategies and attitudes on grades.

In the aspect of learning attitude, Wheatley conducted a research and found encouraging reflection results in greater mathematics achievement, even on standardized tests, which stress procedures and particular conventions [6]. In the aspect of strategies, Pugalee takes the written description strategy as an example. 20 ninth-grade students were investigated in the process of solving algebra problems [7]. The qualitative analysis of students' written descriptions shows that students have a metacognitive framework for solving algebra problems. This framework not only plays an important role in the orientation, organization and execution stage of mathematical problem-solving, but also plays a crucial role in the verification and reflection stage [7].

Although error sorting is regarded as a kind of learning strategy, there are two different views on it in the early stage of the research. The viewpoint represented by Skinner's classical reinforcement theory indicates that wrong behavior should not be reinforced in any way at any time and in any place. Contrary to his view, the scholars represented by Frese proposed that mistakes made while attempting new, difficult activities are certain to occur and that mistakes might be a learning opportunity with a positive connotation. They developed a way of using error training - error management training (EMT), accordingly. Frese's study on computer skills training methods shows that EMT training methods are more effective than error avoidance [8, 9]. It was not until the widespread of constructivist educational thought that researchers generally accepted the sorting of incorrect questions as classroom teaching material. In China, since the concept of error management was put forward late and was deeply influenced by constructivism, Chinese scholars have a relatively consistent understanding of error management. Liu first proposed the concept of error management in the Chinese educational setting. He believed that the students in senior high school in China generally recognized the impact of wrong questions on learning and did not avoid wrong questions emotionally, but they did not know enough about the value of wrong questions [10].

In summary, in the last 20 years, error management has been widely researched in the field of education, especially with the development and application of constructivism. Some researchers, such as Lyons and Zelazo, Pang Wheatley, and Liu, have conducted empirical studies on error management metacognition and they have summarized different processing modes for error management among different periods of students and discovered the relationship between grades and error management strategies [4, 5, 6, 10]. Some researchers, like Zipp et al. and Wen, have conducted studies on the relationship between mind mapping and mathematical problem-solving ability [11, 12]. However, it is noticeable that it still lacks further research in using mind maps to manage error problems and the performance between the management of error problems and the ability of solving mathematical problems. Therefore, this research aims to investigate further in this topic, and four questions will be studied in this paper:

- 1) What is the current situation of the management of mathematical errors in elementary school?
- 2) What is their metacognition status in the management of mathematical errors?
- 3) How is mind mapping used in classroom teaching?
- 4) What is the relationship between using mind maps to manage error math problem and math achievement?

In regard to these questions, this paper adopts a quantitative approach to broadly explore elementary school students' error management capacities and uncover the underlying patterns. By doing this, it is expected to get a thorough understanding of the research questions, which will establish the credibility and dependability of the study.

3. Research Methods

3.1. Participants

The participants in this questionnaire survey are 300 elementary school students in Grades 5 and 6 in three elementary schools in Zhejiang Province. 218 valid questionnaires were collected. In one school, students have been required to use mind mapping for knowledge management since the third grade. In another school, students have been required to conduct error management since this semester. Students of the third school are not expected to carry out any form of knowledge sorting.

3.2. Questionnaire Design

This study designed a 43-item-measure error management metacognitive questionnaire which was adapted from Zhan's questionnaire [2]. In 43 items, there are 35 forward questions and 8 reverse questions, including the concept of mathematical error management. The questionnaire of the subjects involves five aspects: concept, attitude, behavior, strategy, and motivation. Due to the addition of intermediate variables in this study, some new questions were added to the questionnaire to explore the respondents' mind map metacognition. Questionnaire content is guaranteed under the premise of order in each dimension. The content of the degree intersects with each other and the forward and reverse questions are also interspersed. The questionnaire was scored on a five-point Likert scale, in the form of "A. Completely inconsistent", "B. Basically inconsistent", "C. Somewhat consistent", "D. Basic character Agree", "E. Fully agree". In the forward question, A=1 point, B=2 points, C=3 points, D=4 points, and E=5 points whilst reverse questions were graded in reverse, in the calculation of scores A=5 points, B=4 points, C=3 points, D=2 points, and E=1 point.

3.3. Data Analysis

SPSS 27.0 was used to analyze the effective data that was gathered to examine the reliability and validity of measures. The data in the error management metacognition questionnaire were analyzed by correlation analysis and linear regression, to illustrate the role of mind mapping as a mediating variable in the influence of error management on academic achievement.

4. Results

In order to facilitate the study, the 50 participants with the highest total score of the metacognitive questionnaire were set into the high group and the 50 students with the lowest score were set into the low group. Comparing the results of the questionnaire with the results of the latest district test, 86% of the top ten students were in the high group, and only 16% were in the low group. In addition, more than half of the students in the high school group came from schools that had been teaching error management methods for a long time, and only three came from schools that had never taught error management. At the same time, although the results of these three people are higher in the school if they are placed in most classes of the other two schools, it is difficult to rank in the top 5.

The scores of high and low groups in each dimension are shown in the table 1.

Table 1. Scores of High and Low Groups

Category	High Group	Low Group
Concept	3.59	3.06
Attitude	3.11	2.98
Behavior	3.52	2.65
Strategy	3.56	2.42
Motivation	3.51	2.15
Communication	3.89	2.39
Atmosphere	3.58	2.38

From the analysis of statistical results, it can be seen that there is a relatively small gap between high group students and low group students in concept and attitude, especially in attitude. This shows that both high and low group students can realize the importance of error management and complete the error management assignments assigned by teachers meticulously. In the concept dimension, the question with the largest gap in scores was "I believe that timely understanding of math errors will promote the learning of subsequent knowledge." The content of mathematics textbooks in Chinese primary schools is spiraling, that is, the content of teaching is repeated in some knowledge points according to the degree of depth and difficulty, and gradually expanded and deepened. What students do not know at the previous stage will hinder their later learning, and an important function of error management is to address these barriers. The low group of students obviously did not realize the help of error management to learning, so they were also separated from the high group in the dimension of motivation.

Although there is not much difference between the two groups of students' attitudes towards error management in the questionnaire, it has a real impact on the motivation of error management. For example, in "T20. I will sort out math errors every day, every week, or every time after homework or exam papers are issued." Students in the higher group scored 3.54, while those in the lower group scored only 1.78. The above data shows that students in high groups can arrange their own study time to ensure that they can review and sort out their mistakes when they are in the best learning state. Their motivation for math error management is not only to praise teachers but also to find loopholes in math learning. On the other hand, the learning attitude of the students in the low group is similar to that of the students in the high group, which may be due to the authority of the teacher. If the teacher does not assign the wrong homework, they will always avoid the mistakes made in the learning process and will always accumulate the mistakes without taking the initiative to reflect on them. In other words, they do not develop the habit of correcting mistakes in time.

The higher the score on the error management dimension, the more active the students' error management behaviors and the more suitable methods to deal with the wrong questions. The analysis of error management behavior in combination with math scores shows that students with better grades are more active and timelier in managing math errors. The worse the academic performance at ordinary times, the slacker in math error management. The high group in the questionnaire scored 87.4 in the last city test, and there were no students below 80 points, while the low group scored 72.7 points.

Furthermore, the two groups exhibited distinct approaches to error management. The high-achieving students in the group would initially rectify incorrect questions during practice and strategically disregard certain errors arising from calculation mistakes or lower-level errors. Their focus extended beyond merely addressing the incorrect questions; if they encountered challenging problems during practice, they promptly analyzed and categorized them. Conversely, most students in the low-performing group lacked their own error-categorization system. They limited their error management to the exercise book, without analyzing the weak areas of knowledge they had grasped. Additionally, they did not employ mind maps as an aid for summarizing and employing a general problem-solving method.

Error management strategies can have some impact on error communication. For example, T32 "I will learn from other people's mistakes to alert myself not to make the same mistakes" and T26 "I often communicate and share my mistakes with classmates" have a significant correlation (see Table 2). It shows that in the process of learning and communication, the mistakes of others can play a warning role and remind them not to repeat the mistakes. If the error management strategy used by students pays full attention to the role of communication, it can not only make their analysis of the test paper more perfect, but also help them to understand the important and difficult knowledge and distinguish the fallible knowledge.

Table 2. Correlations Between T26 and T32

	26. I often communicate and share my mistakes with classmates.	32. I will learn from other people's mistakes to alert myself not to make the same mistakes.
26. I often communicate and share my mistakes with classmates.	Pearson Correlation Sig. (2-tailed) N	1 .181** 218
32. I will learn from other people's mistakes to alert myself not to make the same mistakes	Pearson Correlation Sig. (2-tailed) N	1 .181** 218

** . Correlation is significant at the 0.01 level (2-tailed).

Finally, the learning atmosphere also affects the students' error management level. If the learning atmosphere of the class regards making mistakes as a shameful behavior, the teacher always treats students' mistakes in learning with a serious attitude, the classmates always laugh at the students who have difficulties in learning, instead of patiently helping them, and the parents attribute all the problems to the children's failure to study seriously. Over time, those students who fall behind temporarily will begin to avoid mistakes and give up on themselves in study. If the teacher ignores the error management too much, the teacher does not give timely feedback after the students have sorted it out, and never uses the students' error management materials to carry out teaching, the students will think that they are doing meaningless things, and the habit of error management will be difficult to maintain for a long time.

All in all, there is a correlation between the seven dimensions of error management, and there is also a significant correlation between the level of error management and student achievement. Through the comparison of the high group and low group, it can be concluded that the two groups have little difference in concept and attitude, which indicates that most students can realize the importance of error management. However, the intrinsic motivation of the two groups is different, resulting in the high group of students actively carrying out error management, the method being more flexible and efficient, the frequency of cooperation and communication between students being higher, and the learning atmosphere more inclusive. On the other hand, low-grade students study for the praise of teachers and parents and mainly deal with homework instead of improving themselves from the heart, which may be related to students' own learning methods, learning atmosphere, and teachers' teaching methods. Among the many error management strategies, the one with the best feedback from students and the one most advocated by teachers in the three schools is the use of mind mapping for management. It can help students to clarify problem-solving ideas, clear their own weak links in learning, and also be conducive to mutual assistance between students. This learning method is widely used in high-group students and low-group students who make rapid progress.

5. Conclusion

This paper mainly investigates the current situation of error management of primary school students and the influence of error management on mathematics achievement. In this paper, it is found that students' ability to internalize knowledge is better when they apply the method of mind mapping in the process of error management than simply extracting wrong questions. In terms of the application of mind mapping, students only use mind mapping to sort out knowledge points has no significant effect on the improvement of math scores. On the contrary, students who utilize mind mapping to categorize the same type of wrong problems, attempt to identify the core steps of solving problems and find a general method tend to have better math scores. At the same time, based on the metacognitive questionnaire of error management, the latter is more flexible in the selection of error question extracts and more serious about error questions. After each practice and exam, they will take the initiative to complete the error question management and are more willing to exchange their own

error question management books with students, and actively absorb and learn from others' excellent and efficient error question management strategies. In addition, if the teacher can use the students' error management resources in the daily classroom teaching process, it will also help the students to develop the habit of error management. The findings match those observed in earlier studies. In Zhan's studies, he finds that students with excellent academic achievement generally outperform students with difficulty in error management strategies, especially in error communication. However, the results of this paper do not reveal that students' degree of error management gradually increases with the growth of grades, which may be related to the fact that schools have never systematically implemented error management strategy teaching. The innovation of this paper lies in taking the mind map as the intermediate variable, systematically teaching students to analyze the knowledge point of the topic by using the mind map, summarizing the general solution of the same type of question, and finding that the error management through the mind map has a positive effect on students' performance. Although this study found that teachers' teaching methods would have an impact on students' error management level, it did not do specific research and could be further studied in the future.

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