

The Effect of Metacognition on University Students' Performance in Mathematics

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Abstract. Mathematics is a basic discipline in fields such as science and engineering, providing a solid theoretical foundation for other disciplines. The study of mathematics major enables college students to deeply understand and apply mathematical principles and lay the foundation for future professional development. College students learning mathematics well is crucial for personal career development and national development. The impact of metacognition on mathematical achievements has long attracted the attention of the education community. This study explores the impact of metacognition on college students' mathematical achievements through questionnaires. Participants included 308 mathematics college students from different grades. The study found that on the whole, metacognition is positively correlated with mathematical scores. Specifically, self-monitoring plays a key role in this relationship. Students who are good at using metacognitive strategies and have good self-monitoring ability are more likely to achieve better math results. Statistics support this discovery and are statistically significant ($p < 0.05$). The research results emphasize the importance of cultivating students' metacognitive skills to improve the mathematical academic level of undergraduate students. However, the study also pointed out the limitations of the investigation and suggested that future research should conduct more in-depth discussions on sample selection and research design.

Keywords: Metacognition, mathematics education, college students, quantitative research.

1. Introduction

The relationship between metacognition and education has attracted the attention of the education community, especially since the learning of mathematics is complex and difficult. Has metacognition played a major role? Mathematical learning can cultivate a highly capable individual with multiple skills to meet the needs of the 21st century [1]. Current research has found that metacognitive learning strategies can be used as an intervention to grasp weak problems [1].

At present, there is relatively little research on the relationship between metacognition and university students' mathematical achievements. It is very meaningful to explore this problem for university students' mathematical learning methods and strategies, as well as teachers' teaching methods. In order to correctly guide university students in mathematics learning and teachers' teaching under the guidance of objective data, this study is based on a questionnaire survey and uses data analysis to explore the impact of metacognition on university students' mathematics performance. This study first measures students' metacognition and mathematical achievements, divides independent metacognition into three parts: metacognition planning strategy, metacognition monitoring strategy, and metacognition evaluation reflection strategy, and then conducts SPSS analysis of the three parts of independent variables and dependent variable mathematical scores, observes the impact of each part of metacognition on mathematical results, and summarizes the rules.

2. Literature Review

2.1. Metacognition

Metacognition theory was proposed by American psychologist John Flavell in 1979. He believes that cognitive ability includes knowledge, memory, and metacognition [2]. In terms of metacognition, metacognitive control refers to the ability to govern one's own cognitive processes, whereas

metacognitive knowledge refers to the awareness of one's own cognitive processes [2, 3]. If people evaluate the quality of ideas and seek to improve them, they will perform metacognitive operations [4]. Metacognitive processes include planning, strategy, knowledge, monitoring, evaluation, and termination [2]. This theory was first used in the field of children's developmental psychology, focusing on children's monitoring and regulation of their own cognitive processes. Over time, metacognition theory has gradually expanded to encompass a vast array of disciplines, including educational psychology, cognitive psychology, and learning strategies. Metacognition is frequently employed in education, particularly to support students in comprehending and mastering subject knowledge. There is now a lot of discussion around the theory of metacognition in language learning and reading education, but not as much research has been done on mathematics. Therefore, this article will examine how metacognition affects undergraduate students' mathematical performance.

2.2. Metacognition and Mathematics Learning

There is a significant positive correlation between metacognition and mathematical achievement in adolescence [5]. There may be a larger correlation between achievement and metacognition among teenagers who successfully complete activities requiring some strategic knowledge, the capacity to monitor grades, and the ability to control metacognitive processing, such as more difficult mathematical tasks. [5]. Similarly, for the youth group, especially undergraduate students, there is a clear positive correlation between their academic performance and metacognition level. According to Xu Yongdong's research on undergraduate students majoring in mathematics, in 2016, metacognition has a certain impact on mathematical problem-solving results, and the scores of different question types are also affected by metacognitive sub-factors [6]. There is no discernible difference between the high-level metacognitive level group and the low-metacognitive level group when solving simple questions, but there is a significant difference when answering challenging difficulties and open-ended questions [6].

2.3. Metacognition in Learning and Teaching

Students with developed metacognition can identify concepts they do not understand and choose appropriate strategies to learn these concepts [7]. They know how to implement the strategy they choose and implement their overall learning plan [7]. They can evaluate their strategies and adjust their plans according to the results [7]. While working in groups, students can stimulate each other's metacognition to improve results [7]. The results of metacognitive awareness of mathematical education through behavior-based metacognitive strategies may increase, especially in analysis [8]. It is suggested to encourage students to improve their metacognition level so as to facilitate their learning outcomes. This paper will further discuss whether students can demonstrate good metacognition in their undergraduate mathematics study and what are the possible teaching approaches for teachers to improve student's metacognition in mathematics learning.

3. Methodology

3.1. Research Design

This study adopts the questionnaire research method to quantitatively analyze and comprehensively understand the impact of metacognition on undergraduate students' mathematical performance. Through the questionnaire survey, a large amount of quantitative data are collected. The questionnaire design includes many aspects of metacognitive levels and realizes a comprehensive analysis of large-scale samples to fully understand the relationship between undergraduate students' metacognition level and mathematical achievements.

3.2. Sample

The participants were 309 undergraduates majoring in mathematics covering different grades and mathematical ability levels. Participants will be invited to complete a questionnaire on metacognitive and mathematical achievements to ensure the diversity and representativeness of participants through systematic sampling. 309 responses were received, one of which was deleted from the data due to invalid data, so a total of 308 valid questionnaires were collected.

Of the 308 effective responses, 40.26% (N=124) were male and 59.74% (N=184) were female. Among them, 21.43% (N=66) of the participants were freshmen, 34.74% (N=107) were sophomores, 30.52% (N=94) were juniors, and 13.31% (N=41) were seniors. By surveying their mathematical scores, it was found that 7.79% (N=24) was between 60 points, 13.31% (N=41) was between 60-70 points, 39.94% (N=123) was between 70-80 points, 28.25% (N=87) was between 80-90 points, and 10.71% (N=33) was between 90-100 points.

3.3. Questionnaire Design

In order to avoid participants' misunderstanding of the problem due to language proficiency, the questionnaire survey adopted the student's first language, Mandarin. Each question in the questionnaire is a single-choice question, and the five options for each question are: A - not like this at all, B - not like this, C - occasionally like this, D - often like this, E - always like this, assigning the five grades of A-E to 1, 2, 3, 4, 5 respectively. First of all, the basic information such as the grade and gender of the participants was collected. This study used the verified metacognition questionnaire to evaluate the metacognition level of participants in terms of metacognitive planning strategies (6 items), metacognitive monitoring strategies (9 items) and metacognitive evaluation reflection strategies (7 items).

3.4. Academic Achievement Record

In terms of the academic score records, the questionnaire collected participants' math course score records as the main basis for quantitative data to understand the overall performance of their mathematics subjects.

3.5. Data Collection

The questionnaire will be widely distributed through online survey tools to improve the convenience and accessibility of data and cover as many participants as possible. Participants will be invited to participate in the questionnaire through the online platform to ensure the timeliness of the data. In addition, the study ensured privacy and rights issues during the questionnaire collection, including clearly informing participants that the data will only be used for research purposes and the results will be processed anonymously.

3.6. Data Analysis

Quantitative data will be analyzed through SPSS statistical software, using descriptive statistics, correlation analysis and regression analysis to quantify the relationship between metacognition and mathematical achievements.

3.7. Limitations of Research

Because the questionnaire adopts the self-presentation method and there is a possible self-presentation bias, researchers need to consider this factor in data analysis. Meanwhile, the score information was reported by the participants themselves, so there may have certain accuracy problems which needed to be handled with caution.

4. Result

This study explores the impact of metacognition on undergraduate students' mathematical achievements through questionnaires. The following are the main research results:

The summary of the survey results shows that there is a significant relationship between metacognition and college students' math scores. Through correlation analysis, which can be seen in Table 1, this paper finds that in general, the metacognitive level is positively correlated with mathematical scores. This means that those students who perform better in metacognition are more likely to achieve better math results.

Further analysis shows that self-monitoring in metacognition has a particularly significant impact on mathematical achievements. Students with good self-monitoring abilities perform better in mathematics and have achieved higher results in the field of mathematics.

Through the statistical analysis of the data, this paper finds that these associations are statistically significant ($p < 0.05$). This strengthens the substantial impact of metacognition on college students' mathematical achievements and provides strong support for further research.

Table 1. Correlation analysis

Questions	Scores
4. Before I do a task, I will set some clear goals.	0.876**
5. I can realize the thinking activities I'm doing.	0.899**
6. In the process of solving the problem, I can realize that I am thinking positively.	0.900**
7. can realize the need to adjust and plan my thinking process.	0.878**
8. I can realize when and what kind of thinking method is used.	0.905**
9. I will divide my time and make long-term and short-term goals accordingly.	0.855**
10. I try my best to find the purpose of the test questions.	0.864**
11. I always try to listen carefully to the pre-examination teacher's instructions and test requirements because I think this information is very important to me, and then I start answering the questions.	0.876**
12. I always start answering questions after thoroughly clarifying the real intention of the questioner, instead of answering according to my subjective ideas and ideas.	0.826**
13. I am sure that I understand "what should be done" and "what should be done"	0.911**
14. When I answer questions, I screen and organize relevant effective information.	0.898**
15. I realize that the "high accuracy" of solving questions is inseparable from the "correct understanding" of question information and solving problems.	0.832**
16. While doing the questions, I checked the accuracy of my understanding in time.	0.887**
17. Every time I encounter difficult questions, I always think, "Why can't I do it?" Or "What is the 'roadblock' of this topic?" Or "Where is the breakthrough in this question?"	0.921**
18. I can check errors by myself with high quality.	0.848**
19. I reflect on my own thinking process, make some corrections and adjustments when necessary, improve my thinking angles and methods, and whether there are easier ways.	0.873**
20. In the process of completing a learning task, I can always ask if I have learned what I really need to learn.	0.841**
21. I can regularly evaluate the performance in the summary stage of learning and reflect on how to do better in the next stage.	0.907**
22. I will reflect on the pros and cons of my original learning plan and strategy.	0.877**
23. Every time I complete a learning task, I like to listen to other people's comments on my performance.	0.899**
24. I can realize that I have made progress from self-evaluation and his evaluation.	0.863**
25. I attach importance to reflecting on the importance of summarizing in my study.	0.882**

* $p < 0.05$ ** $p < 0.01$

This article speculates that this relationship may be related to students' more effective handling of mathematical problems, more organized learning, and more flexible use of cognitive strategies. Learners use metacognitive skills and strategies, such as task analysis, planning, monitoring, inspection and reflection, self- and group monitoring skills, reading and writing skills, self-regulation skills, and self-assessment to help them solve mathematical problems [9]. Metacognitive learning strategies are based on the efficiency of teachers and students in managing teaching and learning, which can cultivate students with good thinking abilities, good self-esteem, and positive tendencies [1]. The design and construction of metacognitive learning strategies should be based on appropriate teaching design models, which are consistent with the operation of metacognitive learning strategies, and choose learning methods to enhance students' abilities [1]. Active learning with high motivation and deep learning will encourage students to plan, monitor, and evaluate the learning process and manage ideological activities [10]. This metacognitive adjustment ability will strengthen students' understanding [10]. Interactive skills, self-regulation skills, and excitement will increase and generate positive experiences, which will have a positive impact on students' attention and actions in the learning process [10]. Therefore, the development concept of mathematical metacognitive activities is a learning activity that combines active learning principles, strategies, and metacognitive adjustment skills [10].

However, there are also limitations of the study, such as the specificity of the sample and the self-report bias of the questionnaire survey. The self-reporting nature of the questionnaire may lead to the subjective bias of the respondent, and the specificity of the sample may limit the generalization of the research results. Future research can use multi-method research design, such as long-term tracking, field observation and in-depth interviews, to more comprehensively understand the relationship between metacognition and mathematical achievements. In addition, this article recommends that future research focus on student groups with different professional and cultural backgrounds to obtain a more global and comprehensive understanding. An in-depth understanding of possible differences between different groups will help the development of personalized education to better meet the learning needs of different students.

Overall, this study reveals the important role of metacognition in the academic performance of college students in mathematics. This is of practical significance for formulating targeted educational strategies to improve students' mathematical ability and is of guiding significance for college students to formulate mathematical learning methods and strategies.

5. Conclusion

From previous studies, metacognition has a significant role in mathematics learning. Through this survey, it also can be found that there is a positive correlation between metacognitive levels and mathematical scores, which means that students' better understanding of their cognitive processes is related to better mathematical performance. This is of far-reaching significance to the education community because it provides educators with a direction to improve teaching strategies and promote the development of students' metacognition. Further analysis shows that self-monitoring strategies play an important role in this relationship. Students with strong self-monitoring abilities are more likely to adjust their learning strategies in real-time to better adapt to the requirements of mathematics. This suggests that cultivating students' metacognitive skills may be an effective way to improve the overall mathematical academic level.

Generally speaking, this study provides an important insight into understanding the impact of metacognition on college students' mathematical performance. These findings have far-reaching implications for educational practice and future research directions, hoping to help build more effective mathematical education strategies and learning methods to promote students' academic success.

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