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# *The Academic Outcomes of Logical Reasoning and Metacognitive Strategy Training for Seventh Graders: Evidence from a Quasi-experimental Design*

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***Abstract:*** Logical reasoning skill is important in people's daily lives, and it is key for students to solve many problems in different subject areas such as mathematics. Research demonstrated that metacognitive strategies play an important role in mediating children's process logical reasoning. This study aimed at developing an intervention with three designed lessons on metacognitive strategies with the purpose to understand the effects of metacognitive strategies on students' logical reasoning skill development. The results of the data analysis demonstrated that a positive effect of the intervention on students' increased logical reasoning skills. The linear regression analysis also indicated that evaluative strategy have a significant impact on logical reasoning ability. This article contributes to the literature by proving that the dimension of evaluative strategy in metacognitive is positively correlated with logical reasoning ability. Future research can study whether other dimensions of metacognition have a significant impact on logical reasoning ability.

***Keywords:*** seventh graders, metacognitive strategy training, logical reasoning training

## 1. Introduction

### 1.1. The Importance of Logical Reasoning

In our study and life, people often confront with the scenario of needing to predict the possible results from the premises, or explore the reasons from the results. This requires the ability of logical reasoning, which has an impact on students' Mathematics scores [1], Chemistry score [2], reading skills [3], etc. Scholars believe that people with high intelligence are good at abstract thinking and reasoning [4]. Jean Piaget indicated that children between the ages of 11 and 15 are in the formal computing stage of cognitive development and they can use language to imagine and think in their minds to solve problems without resorting to specific things. They can also solve problems based on concepts, assumptions, premise, reason, and draw conclusions.

### 1.2. Metacognition and Logical Reasoning

Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them [5]. Since the concept of metacognition was proposed, many scholars have conducted research on it. The research on metacognition mainly focused on the relationship between metacognition and cognition [6], metacognition and non-intellectual factors [7], the relationship between metacognition and learning [8] or problem-solving ability [9], and the development and cultivation of metacognition [10]. Metacognitive experience can affect the process of logical reasoning, and the language expression in reasoning can improve people's understanding of past performance, especially the knowledge that is necessary for successful problem solving [11].

### 1.3. Chinese Middle School Students' Logical Reasoning Ability

The courses in Chinese middle schools emphasize mathematics and logical reasoning skills in geometry, algebra, and probability [12], and Mathematics has become the main front to improve the logical reasoning ability of Chinese children. In primary school, junior middle school and high school, China's "Compulsory Education Mathematics Curriculum Standards (2011 Edition) " incorporates the development of students' reasonable and deductive reasoning abilities into the overall goal of the basic education stage. In the high school section, the "General High School Mathematics Curriculum Standards (2017 Edition) " issued by the Ministry of Education of China puts forward the six core qualities of mathematics, including mathematical abstraction, logical reasoning, mathematical modeling, mathematical operations, intuitive imagination, and data analysis. These new additions to the standards indicate Chinese education not only attaches great importance to the cultivation of students' logical thinking ability, but also focuses on the cultivation of children's logical reasoning ability mainly in mathematics. However, children's logical reasoning ability has not been deeply cultivated in the teaching of other subjects such as language arts. Some experimental results show that Chinese 11-year-old children's syllogism and traditional syllogism reasoning performance is lower than that of French children [13]. Therefore, it is necessary to comprehensively apply the training of logical reasoning ability to other subject areas so that children can transfer logical reasoning ability to the study of other subjects to solve problems.

Chinese scholars attach great importance to the teaching of mathematical logical reasoning, and the research mainly focuses on cultivating students' logical reasoning teaching strategies, teaching models, teaching cases, teaching methods, etc. [12]. However, there are not many studies focused on the intervention of logical reasoning ability at the metacognitive level. Thus, this research aims to develop an intervention to help students improve their logical reasoning ability through the teaching of metacognitive strategies.

## 2. The Relationship of Metacognition and Logical Reasoning

Studies on the relationship of metacognition and logical reasoning generally found that metacognitive strategies play an important role in mediating children's process logical reasoning. For example, Ackerman and Thompson compared meta-memory and meta-reasoning to infer a framework between metacognitive monitoring and reasoning regulation [14]. The relationship between object-level and meta-level cognition is that meta-level regulates object-level by setting goals, deciding appropriate strategies, monitoring their progress and evaluating their effects. Just as metacognition monitors the encoding process and retrieval process of memory and evaluates the probability of successful recall, metacognition will also monitor several judgments in the reasoning process and evaluate the probability of correct reasoning.

Ackerman and Thompson's research in 2017 also showed that metacognitive monitoring and control processes take an important place in all aspects of reasoning, such as initiating and terminating thinking, strategy selection, knowledge monitoring and individual differences [15].

## 3. The Impacts of Metacognitive Intervention on Logical Reasoning

In the past, many studies have used metacognitive teaching to intervene in students' logical reasoning ability. Marjorie Montague examined the influence of cognitive strategies and metacognitive strategy

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teaching on the mathematical problem solving of six middle school students with learning difficulties [16]. Knowledge-metacognitive strategy training can improve students' ability to solve applied reasoning problems, and can transfer the use of strategies to other situations. Kms. Muhammad Amin Fauzi conducted a comparative experiment on two classes and found that the Metacognitive Approach Learning Model can improve the logical and mathematical thinking ability more than the Conventional Learning Model [17]. Mimih Aminah et al also conducted a controlled experiment in two classes and found that for students with intermediate mathematics scores, metacognitive teaching-learning can improve students' logical reasoning ability [18].

## 4. Methods

This study applied a Quasi-experimental design to evaluate the impacts of the intervention on metacognition strategies to develop middle school students' logical reasoning skills. Quasi-experimental design is often used to test causal hypotheses when it is inconvenient to randomize individual or groups to treatment and control groups.

### 4.1. Context and Participants

This study happened in a public middle school in Eastern China. The particular middle school was chosen because the author works in the school and thus has access to students, classrooms, and appropriate resources needed for this study. The particular school is located in Qingdao, Shandong Province and have 1600 students and 140 teachers in total. The enrollment rate for the particular school is 70.0%, the rate of graduating to ordinary high school is 90%.

A total of 4 classrooms at grade 7 that the author is currently teaching were selected to participate in this intervention study. Two of them were randomly selected as the treatment group and the other two were control group. The number of students in each classroom is averaged at about 45-50.

### 4.2. Research Procedures

#### 4.2.1. Data Preparation

An Opt-out form was sent to all the parents to notify them about the details of this study and the potential risks and benefits. Parents who were not willing to let their children to participate in this study were asked to sign the opt-out form. The data of the student whose opt-out form was received will not be included in the data.

#### 4.2.2. The Intervention

The intervention was designed to teach metacognition strategies to 7 graders to help them develop their logical reasoning skills. The intervention includes 3 sessions that target the following aspects. The intervention was only provided to treatment groups. Control group was provided with regular instructions.

##### 4.2.2.1. Session 1: Introduction to Metacognition Strategies

In this session, the author adopted the 6-S model from Hang Lu and introduced each strategy individually: 1. See (see to know what the title says), 2. Speak (speak what the question is asking), 3. Structure (structure the information of the topic into a chart), 4. Strategy (decide what the method to use), 5. Solution (work out the results), 6. Scan (scan to make sure all processes are correct) [19]. A simple practice was provided for students to familiarize with each metacognition strategy.

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#### 4.2.2.2.Session 2: Introduction to Logical reasoning strategy

In this session, the author introduced deduction method, induction method, classification method, elimination method, etc. A simple practice was provided for students to familiarize with each logical reasoning strategy.

#### 4.2.2.3.Session 3: Consolidation and Practice

In this session, the more difficult logical reasoning questions are given to students for consolidation and practice. In this process, students are again inspired how to use metacognitive strategies.

## 4.3. Data Collection

Both treatment and control groups were asked to complete the same set of pre-tests and post-tests.

### 4.3.1. MAI

The Metacognitive Awareness Inventory (MAI) was designed and validated by George Schraw & Rayne Sperling Dennison to evaluate metacognitive knowledge and metacognitive strategies [20]. The MAI includes 52 questions that asked participants to self-evaluate their levels of metacognition awareness from the following constructs: Cognitive Knowledge and Cognitive Management, Cognitive Knowledge including Declarative Knowledge, Procedural Knowledge and Conditional Knowledge, and Cognitive Management including Planning Strategy, Information Management Strategy, Monitoring Strategy, Debugging Strategy and Evaluation Strategy. A total score will be calculated for each participant.

The author adopts the Chinese translated version of MAI from Shaorong Hao [21]. The language was further revised by the author to fit with the level of understanding of 7graders.

### 4.3.2. RPM

Raven’s Progressive Matrices (RPM) was designed and validated by J.c.Raven to evaluate intelligence [22]. The RPM includes 60 problems with increasing difficulty. The test requires the subjects to think and find the law according to some relationship between the graphics in the large pattern, and judge which small pattern is the most appropriate to fill in the missing part of the large pattern, so as to make the whole large pattern complete and form a reasonable and complete whole.

The author adopts the Chinese translated version of RPM from Houcan Zhang [23].

## 4.4. Data Analysis

All the test scores from pre-tests and post-tests were imported into SPSS to run relevant statistical analysis. For the purpose of this study, descriptive analysis, baseline equivalent analysis, independent sample t-tests, and linear regression analysis were conducted respectively on the results of the treatment group and the control group.

# 5. Results

## 5.1. Descriptive Analysis

A descriptive analysis was conducted on the pre-test and post-test results of Metacognition and RPM for both treatment group and control group. The descriptive analysis on the pre-test and post-test results of the treatment group’s Metacognition demonstrates students have grew in most sub-areas of MAI excepts Declarative Knowledge, Information Management Strategy and Debugging Strategy.

Specifically, Metacognition grew 1.02%, Cognitive Knowledge 1.77%、Cognitive Management 0.10%, Procedural Knowledge 2.26%, Conditional Knowledge 4.30%, Planning Strategy 0.89%, Monitoring Strategy 2.15%, Evaluation Strategy 1.97%. Table 1 displays the details described above.

Table 1: Descriptive Analysis of Metacognition and PRM.

| | Treatment Group | | | | Control Group | | | |
|---|---|---|---|---|---|---|---|---|
| | Pro-Test | | Post-Test | | Pro-Test | | Post-Test | |
| | M | SD | M | SD | M | SD | M | SD |
| Metacognition | 181.15 | 30.93 | 182.99 | 33.88 | 185.42 | 36.51 | 188.53 | 38.27 |
| Cognitive Knowledge | 53.22 | 9.53 | 54.16 | 9.72 | 54.78 | 10.91 | 54.58 | 11.68 |
| Cognitive Management | 101.59 | 17.92 | 101.69 | 19.17 | 103.55 | 21.70 | 105.62 | 21.87 |
| Declarative Knowledge | 24.72 | 5.55 | 24.66 | 5.16 | 26.18 | 4.63 | 25.42 | 5.94 |
| Procedural Knowledge | 11.05 | 2.29 | 11.30 | 2.49 | 10.96 | 2.75 | 11.24 | 2.41 |
| Conditional Knowledge | 17.45 | 3.77 | 18.20 | 3.72 | 17.65 | 4.56 | 17.92 | 4.50 |
| Planning Strategy | 20.31 | 4.11 | 20.49 | 4.58 | 20.50 | 5.08 | 21.34 | 5.13 |
| Information Management Strategy | 29.18 | 5.28 | 28.74 | 5.92 | 29.84 | 5.98 | 29.50 | 6.61 |
| Monitoring Strategy | 19.49 | 4.78 | 19.91 | 5.02 | 20.34 | 5.39 | 21.14 | 5.40 |
| Debugging Strategy | 19.96 | 3.55 | 19.65 | 3.55 | 19.66 | 4.10 | 19.96 | 3.87 |
| Evaluation Strategy | 12.66 | 3.91 | 12.91 | 3.45 | 13.22 | 3.95 | 13.69 | 4.07 |

The descriptive analysis on the pre-test and post-test results of the treatment group's RPM scores demonstrated that the logical reasoning skills of the students in treatment group increased. Specifically, the number of correct responses in RPM has increased from average 43.55 to 46.39, increased by 6.52%. Figure 1 demonstrated the detailed numbers changed. The descriptive results generally indicated that the intervention has positive effects on treatment group students' logical reasoning skills.

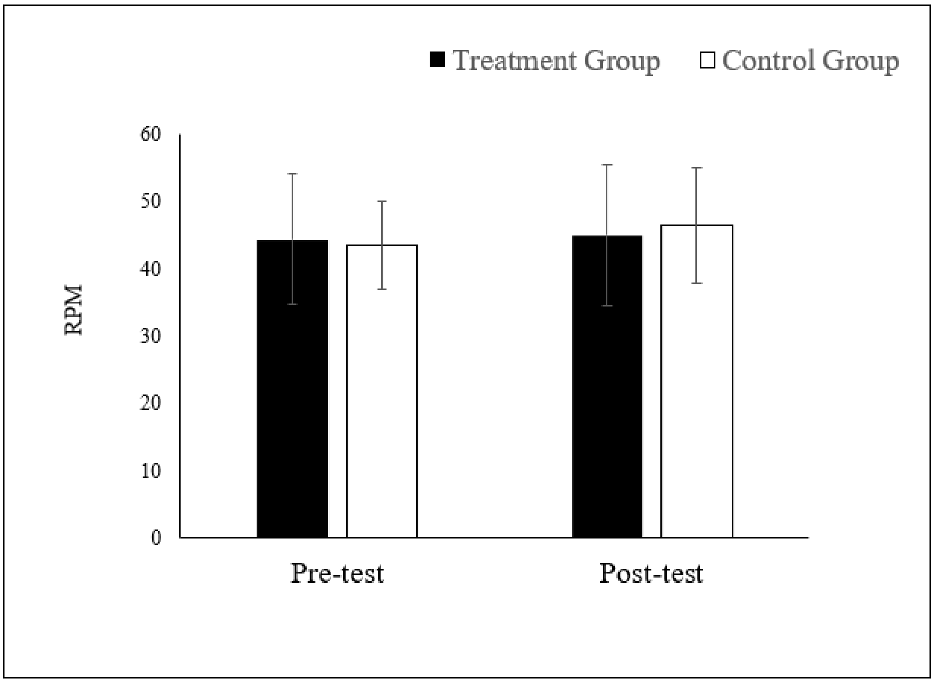


Figure 1: Descriptive Analysis of RPM on the Pre-Test and Post-Test.

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## 5.2. Comparing Treatment and Control Group Pre-test Results

A baseline equivalent analysis was conducted on the pre-test results of both treatment group and control group to understand whether they are baseline equivalent. The purpose of conducting a baseline equivalent analysis is to understand whether the treatment group and control group are similar enough in Cognitive Knowledge and Cognitive Management, Cognitive Knowledge including Declarative Knowledge, Procedural Knowledge and Conditional Knowledge, and Cognitive Management including Planning Strategy, Information Management Strategy, Monitoring Strategy, Debugging Strategy and Evaluation Strategy, the correct number of RPM in order for me to understand whether the intervention conducted later is effective.

I conducted an independent-samples T Test on the pre-tests of both MAI and RPM for the baseline equivalent analysis on treatment group and control group. Table 2 displays the detailed results of the baseline equivalent analysis. Data in Table 2 demonstrates that Metacognition (t=0.769, p>0.05), Cognitive Knowledge (t=0.931, p>0.05) 、Cognitive Management (t=0.599, p>0.05), Declarative Knowledge (t=1.935, p>0.05), Procedural Knowledge (t=-0.227, p>0.05), Conditional Knowledge (t=0.294, p>0.05), Planning Strategy (t=0.249, p>0.05), Information Management Strategy (t=0.713, p>0.05), Monitoring Strategy (t=1.017, p>0.05), Debugging Strategy (t=-0.472, p>0.05), Evaluation Strategy (t=0.858, p>0.05), RPM (t=0.611, p>0.05) are not statistically significant. The results indicates that the treatment group and control group are baseline equivalent before the intervention was conducted.

Table 2: Comparison between Treatment and Control Group (pre-test).

| | Control Group | | Treatment Group | | t | p |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| Metacognition | 185.42 | 36.515 | 181.15 | 30.831 | 0.769 | 0.443 |
| Cognitive Knowledge | 54.78 | 10.912 | 53.22 | 9.526 | 0.931 | 0.353 |
| Cognitive Management | 103.55 | 21.695 | 101.59 | 17.921 | 0.599 | 0.550 |
| Declarative Knowledge | 26.18 | 4.630 | 24.72 | 4.547 | 1.935 | 0.055 |
| Procedural Knowledge | 10.96 | 2.747 | 11.05 | 2.293 | -0.227 | 0.820 |
| Conditional Knowledge | 17.65 | 4.564 | 17.45 | 3.775 | 0.294 | 0.769 |
| Planning Strategy | 20.50 | 5.081 | 20.31 | 4.111 | 0.249 | 0.804 |
| Information Management Strategy | 29.84 | 5.984 | 29.18 | 5.285 | 0.713 | 0.477 |
| Monitoring Strategy | 20.34 | 5.387 | 19.49 | 4.778 | 1.017 | 0.311 |
| Debugging Strategy | 19.66 | 4.096 | 19.96 | 3.552 | -0.472 | 0.638 |
| Evaluation Strategy | 13.22 | 3.946 | 12.66 | 3.914 | 0.858 | 0.393 |
| Raven’s Progressive Matrices | 44.38 | 9.650 | 43.55 | 6.538 | 0.611 | 0.542 |

## 5.3. Comparing Treatment and Control Group Post-test Results

The independent sample t-test for the post test of the experimental group and the control group is to compare whether there are differences between the experimental group and the control group after the experiment.

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Table 3: Comparison between Treatment and Control Group (post-test).

| | Control Group | | Treatment Group | | t | p |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| Metacognition | 188.53 | 38.267 | 182.99 | 33.087 | 0.942 | 0.348 |
| Cognitive Knowledge | 54.58 | 11.681 | 54.16 | 9.718 | 0.237 | 0.813 |
| Cognitive Management | 105.62 | 21.867 | 101.69 | 19.170 | 1.163 | 0.247 |
| Declarative Knowledge | 25.42 | 5.936 | 24.66 | 5.161 | 0.828 | 0.409 |
| Procedural Knowledge | 11.24 | 2.415 | 11.30 | 2.492 | -0.134 | 0.894 |
| Conditional Knowledge | 17.92 | 4.502 | 18.20 | 3.716 | -0.418 | 0.676 |
| Planning Strategy | 21.34 | 5.129 | 20.49 | 4.579 | 1.065 | 0.289 |
| Information Management Strategy | 29.50 | 6.607 | 28.74 | 5.924 | 0.734 | 0.464 |
| Monitoring Strategy | 21.14 | 5.402 | 19.91 | 5.021 | 1.434 | 0.154 |
| Debugging Strategy | 19.96 | 3.869 | 19.65 | 3.548 | 0.509 | 0.611 |
| Evaluation Strategy | 13.69 | 4.071 | 12.91 | 3.453 | 1.263 | 0.209 |
| Raven's Progressive Matrices | 45.00 | 10.453 | 46.39 | 8.511 | -0.888 | 0.376 |

Table 3 displays the detailed results of the baseline equivalent analysis. Data in Table 2 demonstrates that Metacognition (t=0.942, p>0.05), Cognitive Knowledge (t=0.237, p>0.05), Cognitive Management (t=1.163, p>0.05), Declarative Knowledge (t=0.828, p>0.05), Procedural Knowledge (t=-0.134, p>0.05), Conditional Knowledge (t=-0.418, p>0.05), Planning Strategy (t=1.065, p>0.05), Information Management Strategy (t=0.734, p>0.05), Monitoring Strategy (t=1.434, p>0.05), Debugging Strategy (t=0.509, p>0.05), Evaluation Strategy (t=0.263, p>0.05) RPM (t=-0.888, p>0.05) are not statistically significant. The results indicates that there was no significant difference between the experimental class and the control class.

## 5.4. Comparing the Pre-Test and Post-Test of the Treatment Group

The paired sample T-test of Metacognition, Cognitive Knowledge, Cognitive Management, Cognitive Knowledge, Declarative Knowledge, Procedural Knowledge, Conditional Knowledge, Cognitive Management, Planning Strategy, Information Management Strategy, Monitoring Strategy, Debugging Strategy, Evaluation Strategy, and RPM was to analyze whether there are significant changes in various indicators of students in the Treatment Group after the experiment.

Table 4 Comparison between Pre-Test and Post-Test of the Treatment Group.

| | Pro-Test | | Post-Test | | t | p |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| Metacognition | 181.15 | 30.831 | 182.99 | 33.087 | -0.732 | 0.467 |
| Cognitive Knowledge | 53.22 | 9.526 | 54.16 | 9.718 | -1.162 | 0.249 |
| Cognitive Management | 101.59 | 17.921 | 101.69 | 19.170 | -0.062 | 0.951 |
| Declarative Knowledge | 24.72 | 4.547 | 24.66 | 5.161 | 0.105 | 0.917 |
| Procedural Knowledge | 11.05 | 2.293 | 11.30 | 2.492 | -1.026 | 0.308 |
| Conditional Knowledge | 17.45 | 3.775 | 18.20 | 3.716 | -2.314 | 0.023 |
| Planning Strategy | 20.31 | 4.111 | 20.49 | 4.579 | -0.493 | 0.623 |
| Information Management Strategy | 29.18 | 5.285 | 28.74 | 5.924 | 0.786 | 0.434 |
| Monitoring Strategy | 19.49 | 4.778 | 19.91 | 5.021 | -0.887 | 0.378 |
| Debugging Strategy | 19.96 | 3.552 | 19.65 | 3.548 | 0.903 | 0.369 |
| Evaluation Strategy | 12.66 | 3.914 | 12.91 | 3.453 | -0.580 | 0.564 |
| Raven's Progressive Matrices | 43.55 | 6.538 | 46.39 | 8.511 | -3.031 | 0.003 |

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Data in Table 4 demonstrates that Metacognition (t=-0.732, p>0.05), Cognitive Knowledge (t=-1.162, p>0.05), Cognitive Management (t=-0.062, p>0.05), Declarative Knowledge (t=0.105, p>0.05), Procedural Knowledge (t=-1.026, p>0.05), Planning Strategy (t=-0.493, p>0.05), Information Management Strategy (t=0.786, p>0.05), Monitoring Strategy (t=-0.887, p>0.05), Debugging Strategy (t=0.903, p>0.05), Evaluation Strategy (t=-0.580, p>0.05) are not statistically significant. The results indicates that the education program has no obvious effect on these indicators.

There are significant differences in Conditional Knowledge (t=-2.314, p<0.05), and RPM (t=-3.031, p<0.05), indicating that this education program had a clear impact on these 2 indicators.

## 5.5. Comparing the Pre-Test and Post-Test of the Control Group

The paired sample T-test of Metacognition, Cognitive Knowledge, Cognitive Management, Cognitive Knowledge, Declarative Knowledge, Procedural Knowledge, Conditional Knowledge, Cognitive Management, Planning Strategy, Information Management Strategy, Monitoring Strategy, Debugging Strategy, Evaluation Strategy, and RPM was to analyze whether there are significant changes in various indicators of students in the Control Group after the experiment.

Data in Table 5 demonstrates that Metacognition (t=-1.062, p>0.05), Cognitive Knowledge (t=0.221, p>0.05), Cognitive Management (t=-1.080, p>0.05), Declarative Knowledge (t=1.521, p>0.05), Procedural Knowledge (t=-1.123, p>0.05), Conditional Knowledge (t=-0.647, p>0.05), Planning Strategy (t=-1.953, p>0.05), Information Management Strategy (t=0.536, p>0.05), Monitoring Strategy (t=-1.629, p>0.05), Debugging Strategy (t=-0.616, p>0.05), Evaluation Strategy (t=-1.002, p>0.05) and RPM (t=-1.287, p>0.05) are not statistically significant.

Table 5: Comparison between Pre-Test and Post-Test of the Control Group.

| | Pro-Test | | Post-Test | | t | p |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| Metacognition | 185.42 | 36.515 | 188.53 | 38.267 | -1.062 | 0.292 |
| Cognitive Knowledge | 54.78 | 10.912 | 54.58 | 11.681 | 0.221 | 0.826 |
| Cognitive Management | 103.55 | 21.695 | 105.62 | 21.867 | -1.080 | 0.284 |
| Declarative Knowledge | 26.18 | 4.630 | 25.42 | 5.936 | 1.521 | 0.133 |
| Procedural Knowledge | 10.96 | 2.747 | 11.24 | 2.415 | -1.123 | 0.265 |
| Conditional Knowledge | 17.65 | 4.564 | 17.92 | 4.502 | -0.647 | 0.520 |
| Planning Strategy | 20.50 | 5.081 | 21.34 | 5.129 | -1.953 | 0.055 |
| Information Management Strategy | 29.84 | 5.984 | 29.50 | 6.607 | 0.536 | 0.593 |
| Monitoring Strategy | 20.34 | 5.387 | 21.14 | 5.402 | -1.629 | 0.108 |
| Debugging Strategy | 19.66 | 4.096 | 19.96 | 3.869 | -0.616 | 0.540 |
| Evaluation Strategy | 13.22 | 3.946 | 13.69 | 4.071 | -1.002 | 0.320 |
| Raven's Progressive Matrices | 44.38 | 9.650 | 45.11 | 10.482 | -1.287 | 0.202 |

## 5.6. Linear Regression Analysis

The Linear Regression method of Multiple Regression was used to analyze the influence of Metacognition, Cognitive Knowledge, Cognitive Management, Declarative Knowledge, Procedural Knowledge, Conditional Knowledge, Planning Strategy, Information Management Strategy, Monitoring Strategy and Correction Strategy on the RPM.

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Table 6 Linear Regression Analysis of Metacognitive Dimensions and RPM.

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .241 | 0.058 | 0.051 | 8.000 |

As shown in Table 6, the R-square of the model is 0.058, indicating that the explanatory degree of the Evaluation Strategy to the dependent variable RPM is 0.058.

Table 7: Analysis of Variance of Regression.

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 570.435 | 1 | 570.435 | 8.913 | .003 |
| Residual | 9280.395 | 145 | 64.003 | | |
| Total | 9850.830 | 146 | | | |

Table 8: Regression Coefficient Table.

| Variable | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (Constant) | 37.422 | 2.289 | | 16.348 | 0.000 |
| Evaluation Strategy (Pre-Test) | 0.504 | 0.169 | 0.241 | 2.985 | 0.003 |

Data in Table 7 demonstrates that $F=8.913$, $p<0.01$, indicating that the independent variable Evaluation Strategy has a significant impact on the dependent variable RPM.

From the results of regression coefficient and its significance test, the Evaluation Strategy (Pre-Test) has a positive impact on RPM.

## 6. Discussion and Conclusion

This study aimed to develop an intervention attempting to increase students' logical reasoning skills with three designed lessons on Metacognition. The data analysis indicated that students' Metacognition increased slightly in most areas and their corrected RPM scores increased after the intervention, which indicating a positive effect. The literature on the relationship of metacognition and logical reasoning generally found that metacognitive strategies play an important role in mediating children's process logical reasoning. Since the intervention attempted to increase students' logical reasoning skills with targeted lessons on framing students' metacognitive strategies, the increasing of the corrected RPM after the intervention indicates the intervention is effective.

T-test results demonstrated that only Conditional Knowledge, one sub-area of Metacognition, and RPM grew significantly after the intervention. The linear regression analysis demonstrated that only Evaluation Strategy has a positive impact on RPM. All dimensions of Metacognition in the Treatment Group did not increase much after the intervention. T-Test analysis of the Pre-Test and Post-Test of the Treatment Group showed that only the Conditional Knowledge and RPM increased significantly. The possible reasons are: (1) most of the interventions I designed are aimed at conditional knowledge, such as what 6S strategy is, why and how to use it. These belong to the scope of conditional knowledge, so only conditional knowledge increases significantly after the intervention; (2) the duration of intervention.

Linear Regression Analysis shows that Evaluative Strategy have a significant impact on logical reasoning ability. Evaluative Strategy refers to the ability to analyze the effectiveness of grades and strategies after learning. Therefore, Evaluative Strategy have a significant impact on logical reasoning ability, which shows that improving students' ability to analyze and evaluate the effectiveness of their own grades and strategies can improve their logical reasoning ability. Studies on the relationship between metacognition and logical reasoning ability generally show that metacognitive strategies are related to logical reasoning ability, but few articles specifically study which dimension of metacognition are related to logical reasoning ability. Therefore, the contribution of this article is to prove that the dimension of Evaluative Strategy in Metacognitive is positively correlated with logical reasoning ability. Future research can try to study whether other dimensions of Metacognition have a significant impact on logical reasoning ability.

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