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# Navigating Math Minds: Unveiling the Impact of Metacognitive Strategies on 8th Grade Problem-Solvers Abilities

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## Abstract

The current study was designed to examine the effect of metacognitive instruction strategies on the development of metacognition in grade 8 students and study variation in the development of metacognition in students with varying academic abilities. The study involved 80 grade 8 students from a public high school as a sample. A quasi-experimental non-equivalent control group research design was used to conduct research. The Junior Metacognitive Inventory Jr. MAI, developed by Sperling et al. (2002), was administered to assess metacognition in both experimental and control groups four times throughout the experiment, at baseline, and after each of the three stages. The experimental group was taught mathematical problem-solving using metacognitive teaching strategies (such as self-questioning, thinking aloud, modelling, and concept mapping). On the contrary, the control group received training using the traditional lecture method during the 18-week intervention. The results show that metacognitive instructional strategies used during the experiment significantly affect the growing metacognition, knowledge of cognition, and regulation of cognition of grade 8 students during Mathematical problem-solving teaching. Furthermore, the metacognition of all subgroups was significantly enhanced after teaching through metacognitive instructional strategies. Mathematics teachers are recommended to spread awareness about metacognition and metacognitive instructional design to improve math problem-solving skills among elementary-level students.

**Keywords:**

Metacognitive Instructions, Knowledge of Cognition, Regulation of Cognition, Teaching Strategies

## Introduction

Over the last few decades, metacognition has been recognised as a powerful predictor of mathematical problem-solving skills. Substantial studies have demonstrated metacognition's function on students' instructional achievement. Students with better metacognition usually have more potential to display and adjust their cognitive abilities, allowing them to perform higher academically (Pintrich, 2002). The math achievement of eighth graders was strongly correlated with their metacognition. This helps to confirm that higher metacognition in students would lead to excel in mathematics (Habib & Rana, 2020).

A psychological concept called metacognition was coined by Flavell (1979). It is defined as a person's knowledge of one's thoughts and ability to control or govern them (De-Jager et al., 2005; Hacker & Dunlosky, 2003). It can be summed up as "thinking about thinking" in simple terms (Flavell, 1979). Metacognition is distinct from an individual's overall intelligence in that it can be considered a collection of general talents instead of domain-specific skills. In solving problems, metacognitive tendencies typically compensate for a person's lack of knowledge and general intelligence (Schraw, 1998).

Metacognitive knowledge and metacognitive control or regulations are the two subtopics covered when discussing metacognition (Otani & Widner, 2005; Sungur, 2007). Metacognitive knowledge is understanding a person's intellectual existence, capacities, and limits (Brown, 1987; Jacobs & Paris, 1987; Schraw et al., 2006). The second sub-concept of metacognition, known as metacognitive control or regulation, refers to "the behaviours utilised to manage and oversee learning" (Brown, 1987). These are called the steps taken to manage and regulate learning.

Developing metacognitive skills was a challenging task after the acknowledgement of metacognition and its importance. Furthermore, enormous research supports this belief that metacognition is a skill that can be learned and improved (Dignath et al., 2008; Kramarski & Mevarech, 2003; Ozsoy & Ataman, 2009).

The development of metacognition in a being is a continuous but stable process. Previous research supports the belief that metacognition development does not inherently progress with age (Baker & Beall, 2014). Instructions are more helpful than ageing and experience in helping people build their metacognitive skills (Veenman et al., 2004). Through knowledge and self-regulation of their skills, students may be able to keep track of their learning processes using metacognitive instructions (Brown, 1982).

There is considerable literature suggesting instructional strategies to develop metacognition. However, the most effective approaches combine theory and practice (Amjad et al., 2023; Aslam et al., 2021). Declarative, procedural, and conditional knowledge is acquired through theoretical lessons, and metacognition regulation is supported by practising effective strategies (Livingston, 2003).

Self-questioning, teacher and peer modelling, scaffolding, think-aloud, and checklists are research-based examples of metacognitive educational practices. These techniques help students stimulate their cognitive skills and regularly regulate an individual's intellect for all tasks (Amjad et al., 2022; a, b; Gama, 2005). It is inevitable to equip our teachers with the knowledge of explicit metacognitive strategies and the effective use of those to develop metacognition among students (Schraw, 1998; Schraw et al., 2006). Researchers have always found it difficult to evaluate metacognition since it is a complex concept that cannot be observed through people's direct, explicit actions (Sperling et al., 2002). Since 1979, various tools have been used to measure metacognition. Each technique has advantages and disadvantages (Panaoura & Philippou, 2005).

Various tools have been used to measure metacognition from the beginning of the construct (e.g. questionnaires, observation, interviews, Thinking aloud, stimulated recall, etc). All of the instruments used possess their context-based strengths and challenges (Veenman & van Cleef, 2019). Metacognitive Awareness Inventory (MAI) has been used extensively to measure metacognitive since 1979. Metacognitive Awareness Inventory MAI consists of self-report questions based on two main components: knowledge of cognition and regulation of cognition (Schraw & Dennison, 1994). Simultaneously, Jr.MAI, by Sperling et al. (2002), is a widely used tool for measuring the metacognition of children of two different age groups. These two inventories will likely be considered independent of domain rather than domain-specific (Ellah et al., 2023).

A recent study concluded after two experiments that reevaluating metacognition improves the previous results after providing feedback to the subjects (Elosegi et al., 2024). Veenman and van Cleef (2019) conducted another interesting study to compare the metacognition measurement through five different instruments at different instances, and the results were compared.

The think-aloud approach is one of the operational methods to assess metacognition. Students are asked to express their mental processes, which are then recorded, transcribed and subjected to scientific analysis (Akram et al., 2023; Veenman & Spaans, 2005). The metacognitive interview by Myers and Paris (1978) is one of the first instruments to measure metacognition for older readers. The most common technique for evaluating Mc is thought to be a metacognitive questionnaire.

Due to the simplicity of administration, even for a large sample, and ease and comfort, they may be used to evaluate acquired data (McCormick et al., 2013). Schraw and Dennison (1994) created the Metacognitive Awareness Inventory (MAI), widely used to assess metacognition. There are 52 items, each worth five points, making up a complete self-report inventory for adults founded on knowledge, regulation, and sub-constructs of these fundamental Mc components. Adult metacognition is measured using the Schraw and Dennison (1994) metacognitive awareness inventory. To measure Mc in kids of two different age groups, Sperling et al. (2002) adjusted this as Jr.MAI.

Junior Metacognitive Inventory Jr. MAI, Versions A and B, each containing 12 items for grades 3-5 and 18 for grades 6–9. As previously noted, the above inventories are frequently employed to assess adults and children's metacognition (Panaoura & Philippou, 2005).

### *Significance of the Study*

Mathematical problem-solving is one of the thought-provoking processes which needs higher-order skills like metacognitive abilities. Adequate research literature is available to support the effective use of self-regulative skills like metacognitive abilities for a self-assured effort for a Mathematical problem. Metacognition is likely to be a substantial pre-requisite for self-regulated learning, comprised of two basic constructs: knowledge and regulation of cognition (Dörr & Perels, 2019). Regardless of the considerable effects of metacognitive strategies in research classrooms, such inspirational activities could hardly be found in real classrooms. The problem is possibly rooted in the dearth of teachers' friendly instructional strategies in real-world classrooms for problem-solving (Ozturk, 2022). Generally, struggling students in Mathematics are intrinsically less motivated and possess low metacognitive levels as compared to high performers (Desoete & De-Craene, 2019). At the same time, the effective use of metacognitive instructional strategies for developing Mathematical problem-solving skills has been a neglected area in the Pakistani context. Metacognition-related literature lacks the study of variation in developing Mathematical problem-solving skills among elementary students with diverse academic abilities. Investigating an effective use of metacognitive instructional strategies for a real classroom teaching on the diversity of groups of students in Mathematical problem-solving skills settings is an evolving gap in metacognitive research. The present study aimed to compare the Mathematical problem-solving abilities of above-average, average and below-average achievers with metacognitive instructional strategies.

### *Objectives of the Study*

The objectives of the present study were the following.

1. To compare the metacognition of eighth graders taught through the lecture method and metacognitive instructional strategies.
2. To compare the effectiveness of metacognitive instructional strategies on above-average, average, and below-average students' metacognition during Mathematical problem-solving.

### *Hypotheses of the Study*

The following hypotheses were developed to achieve the objectives of the study.

$H_{01}$: There is no significant difference between the mean scores of metacognition of the 8th graders, those taught through the lecture method, and those using metacognitive instructional strategies.

$H_{02:}$ There is no significant variation in the effectiveness of metacognitive instructional strategies in mean metacognition scores from eighth graders with varying abilities.

### *Delimitation of the Study*

Private schools use a range of curricula, instructional techniques, suggested reading lists, and assessment techniques. Due to the uniformity in their curricula and evaluation procedures, the present study was limited to eighth graders studying in government schools. Only those units containing problem-solving themes were chosen from the Mathematics 8 of Punjab textbook board for the study.

## Methodology

The nature of the study was quantitative. To conduct the study, a quasi-experimental nonequivalent control group pretest-posttest design was used. Nonrandom assignment was used to choose two intact groups, an experimental group (n=40) and a control group (n=40). Metacognitive instructional strategies were the study's independent variable, while metacognition values of grade 8 students were the dependent variable.

The experimental group was exposed to teaching mathematical problem-solving skills by using metacognitive teaching techniques like self-questioning, teacher and peer modelling, scaffolding, think-aloud, and checklists. However, the same content was taught to the control group using the traditional method (lecture). Both groups were comparable in using the same course materials, schedule, and assessments. A pretest and post-test design perfectly compares the degree of change resulting from the intervention. Participants in this study were 80 8th-grade female students from the Government Girls High School in the Lahore district. The average age of the research participants was about 12 or 13 years during the experiment.

During the twenty weeks of the experiment, both groups were taught five lessons per week, each lasting 40 minutes. The content for teaching was taken from the Punjab Mathematics textbook board, related to ratio/proportion, percentage, and simultaneous linear equations, as these topics cover mathematical problem-solving (statement questions). All the topics were planned through lesson plans involving metacognitive instructional strategies for the experimental group.

The walls of the classroom of the experimental group were covered with a few charts related to the concept of "metacognition" and its elements. Teaching aids, including a checklist and instructional tactics, were also displayed on the walls. These specific arrangements were made to conduct the experiment more effectively. The teacher herself vocalised her thinking developed during the Mathematical problem-solving process to train the students for modelling techniques to establish the regulation of cognition. After presenting new challenges to the experimental group, regular classroom instruction also used the students' modelling and concept mapping strategies. To control students' metacognitive growth, students were given cards describing a checklist (Schraw, 1998) of self-questioning while working through issues. On the other hand, the control group was taught the same topics using the traditional teaching method.

Researchers have always found it difficult to evaluate metacognition since it is a complex concept that cannot be observed in people's immediate, explicit actions (Sperling et al., 2002). Since 1979, researchers have used various tools effectively to assess metacognition. For the present study, Sperling et al. (2002) Junior Metacognitive Inventory or Jr. MAI was used to measure metacognition in grade 8 students. It is a modified version of the metacognitive awareness inventory developed by Schraw and Dennison (1994), which assesses adults' metacognition. With a Cronbach alpha of .85, we recalculated in our study, which was found to be .84, above the threshold level of .70 for the social sciences. The Junior Metacognitive Inventory Jr. MAI by Sperling et al. (2002) is acknowledged as a trustworthy tool (Sperling et al., 2002). The metacognitive inventory consists of 18 statements. Nine statements assess cognition knowledge, while the remaining nine measure cognition regulation.

Jr. MAI. Aydin and Ubuz (2010) transformed it into Turkish and used it to collect data about students' metacognition. Their study found Cronbach's alpha of the Turkish version to be .88 of Jr. MAI. Subsequently, Kirbulut (2014) also used the same version.

Considering the limited English language skills of Pakistani students, Jr. MAI has been translated into Urdu (an innate language) by a group of language experts to help the kids understand the statements and answer quickly.

To ensure appropriate comprehension of the content in both languages, the Urdu translation of the inventory was translated back into English. The expert opinion of a few educational researchers ensured the instrument's content validity. Through a pilot study on 100 students in grade 8, data were collected using the Jr. Junior Metacognitive Inventory. MAI (Urdu version) and construct validity were ensured by factor analysis of the data collected—the Urdu version of the Jr. The MAI metacognitive inventory reliability score was 0.92.

The Metacognitive Inventory Jr. MAI (Sperling et al., 2002) was administered four times throughout the experiment to measure metacognition before and after each step. The factor loadings given in Table 1 show the results of the factor analysis.

The Jr. MAI factor analysis produced five-factor solutions. The results showed that a five-factor solution loaded the statements to explain 64.68 percent of the variation. Table 2 shows the features of the factors and the matching statements.

In Table 2, the researchers presented five overall factors for MAI: knowledge of cognition, eight statements; planning and information management, two statements for each factor; and monitoring and evaluation, three statements for each factor.

Table 3 shows the mean, standard deviation and reliability analysis of five factors of Jr. MAI.

$H_{01}$: There is no significant difference between the mean scores of metacognitions of the 8th graders, those taught through the lecture method and using metacognitive instructional strategies.

Hypothesis H01 was tested using repeated-measure ANOVA. Its foundation is the sphericity assumption, which verifies that the variance of scores based on the population difference is independent of any two conditions, i.e., remains the same for any two conditions. In such a situation, the Mauchly test of sphericity is applied to gauge the validity of this assumption. Although it is unfortunate that this assumption is frequently broken, there are ways to compensate.

The assumption of sphericity has been broken since the significant value of 0.000 is less than the crucial value of 0.05, indicating substantial differences between variances of differences. Fortunately, we can simply alter the degrees of freedom, for the impact of data does not conform to the sphericity assumption. The range of the Greenhouse-Geisser estimate () is 1/k-1 to 1. (where k is the number of degrees). 1/k-1 for the observed data is 0.25, which is less than 0.75. The data are, therefore, corrected for sphericity violations using the Greenhouse-Geisser estimate of sphericity (Girden, 1992; Barcikowski & Robey, 1984; Huynh & Feldt, 1976).

Our null hypothesis H01 is rejected because the results of Table 5 demonstrate that the value of metacognition is significantly influenced by metacognitive instructional

**Table 1**

*Factor loadings by Principal Component Factor Analysis of Metacognitive Inventory Rotated by Varimax with Kaiser Normalization*

| Statement no. | Factor 1 Knowledge | Factor 2 Planning | Factor 3 Information Management | Factor 4 Monitoring | Factor 5 Evaluation |
|---|---|---|---|---|---|
| S12 | 0.782 | | | | |
| S13 | 0.642 | | | | |
| S16 | 0.648 | | | | |
| S1 | 0.568 | | | | |
| S2 | 0.549 | | | | |
| S14 | 0.546 | | | | |
| S4 | 0.384 | | | | |
| S5 | 0.381 | | | | |
| S18 | | 0.733 | | | |
| S9 | | 0.649 | | | |
| S11 | | | 0.918 | | |
| S6 | | | 0.801 | | |
| S10 | | | | 0.787 | |
| S8 | | | | 0.778 | |
| S15 | | | | 0.703 | |
| S17 | | | | | 0.783 |
| S7 | | | | | 0.740 |
| S3 | | | | | 0.626 |

**Table 2**

*Factor-wise Statements after Factor Loadings*

| Factor | Statements | Item conceptual affiliation |
|---|---|---|
| Factor 1 | S1, S2, S4, S5, S12, S13, S14, S16 | Knowledge of cognition |
| Factor 2 | S9, S18 | Planning |
| Factor 3 | S6, S11 | Information management |
| Factor 4 | S8, S10, S15 | Monitoring |
| Factor 5 | S3, S7, S17 | Evaluation |

**Table 3**

*Descriptive and Reliability Analysis of Jr. MAI Inventory with its Major Factors*

| Factor | Primary affiliation | N | No. of items | Mean | SD | Cronbach Alpha |
|---|---|---|---|---|---|---|
| 1 | Knowledge of cognition | 100 | 8 | 19.21 | 3.816 | 0.794 |
| 2 | Planning | 100 | 2 | 3.42 | 1.703 | 0.939 |
| 3 | Information management | 100 | 2 | 5.94 | 1.530 | 0.921 |
| 4 | Monitoring | 100 | 3 | 5.61 | 2.324 | 0.960 |
| 5 | Evaluation | 100 | 3 | 5.78 | 2.373 | 0.887 |

**Table 4**

*Mauchly's test of the sphericity of metacognition measures*

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Greenhouse-Geisser (Epsilon$^b$ ) |
|---|---|---|---|---|---|
| MAI | .674 | 28.537 | 5 | .000 | .767 |

**Table 5**

*Metacognition Scores of Three Intervention Steps for the Control and Experimental Group*

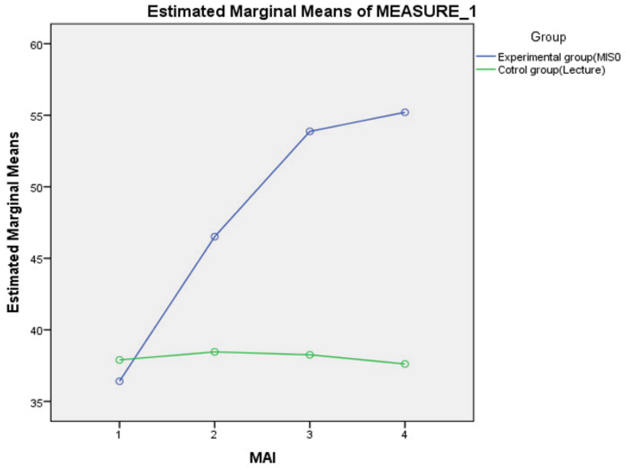
| | Control | | | Experimental | | |
|---|---|---|---|---|---|---|
| | N | Mean | SD | N | Mean | SD |
| M1 Pre-intervention | 38 | 37.80 | 5.655 | 38 | 36.42 | 6.133 |
| M2 Post-intervention Stage 1 | 38 | 38.47 | 6.522 | 38 | 46.52 | 6.202 |
| M3 Post-intervention Stage 2 | 38 | 38.25 | 3.624 | 38 | 53.86 | 6.713 |
| M4 Post-intervention Stage 3 | 38 | 37.52 | 4.602 | 38 | 55.23 | 7.848 |
| F | 162. 292 | | | | | |
| Df | 2.332 | | | | | |
| Sig. | .000 | | | | | |
| Partial Eta squared | .681 | | | | | |

strategies, *F* (2.332, 177.236) = 162. 292, *p* = 0.000 at the level of significance 0.5. Accordingly, it can be said that metacognitive instructional strategies significantly affect the metacognitive scores of eighth graders in mathematics.

A partial Eta squared value (.681) further documented the significant effect of metacognitive teaching techniques on Mc values during three stages of the intervention for the current study, strongly suggesting a very large effect size. Figure 1 below shows the graphical representation of metacognition in the experimental and control groups at various stages.

**Figure 1**

*Graphical Representation of Metacognition of Experimental Group and Control Group at Four Stages*



The experimental group's metacognition mean scores clearly change (rise), while the control group's mean scores stay the same during the study's four measuring instants. The experimental group's mean Mc scores increased significantly after the intervention. This supports the finding that metacognitive instructional strategies significantly affect 8th graders' metacognition when they are completing mathematical problems.

$H_{02}$: There is no significant variation in the effectiveness of metacognitive instructional strategies on mean metacognition scores of eighth graders with varying abilities.

**Table 6**

*Mauchly's Test of Sphericity for Effect on Metacognition of 8$^{th}$ Graders with Varying Abilities*

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Greenhouse-Geisser (Epsilon$^{b}$) |
|---|---|---|---|---|---|
| The gain in MAI scores with varying ability | .805 | 15.279 | 5 | .008 | .854 |

As a significant value of 0.008 is less than the critical value of 0.05, it means that there are significant differences between variances of differences and therefore, the condition of sphericity has been violated. Fortunately, if data violate the sphericity assumption, we adjust the degrees of freedom for effect. The Greenhouse-Geisser estimate () varies between 1/k-1 and 1(where k is a number of degrees). For the current data, 1/k-1 is 0.25, which is less than 0.75. Therefore, Greenhouse-Geisser's estimate of sphericity is used to correct the data to avoid violations of sphericity (Barcikowski & Robey, 1984; Girden, 1992; Huynh & Feldt, 1976).

**Table 7**

*Descriptive analysis of mean score scores of cognitive behaviours of students with varying abilities before intervention and in three steps of intervention*

| Groups | Metacognition | Control | | | Experimental | | |
|---|---|---|---|---|---|---|---|
| | | N | M | SD | N | M | SD |
| Above Average | M1 | 9 | 44.1 | 1.968 | 9 | 44.1 | 2.827 |
| | M2 | 9 | 45.4 | 1.775 | 9 | 53.4 | 2.977 |
| | M3 | 9 | 41.7 | 3.916 | 9 | 60.11 | 2.377 |
| | M4 | 9 | 42.5 | 2.954 | 9 | 62.71 | 2.358 |
| Average | M1 | 18 | 38.16 | 4.030 | 18 | 36.25 | 2.977 |
| | M2 | 18 | 37.53 | 3.703 | 18 | 45.67 | 3.903 |
| | M3 | 18 | 37.79 | 2.551 | 18 | 55.38 | 4.548 |
| | M4 | 18 | 37.53 | 2.912 | 18 | 56.33 | 5.974 |
| Below Average | M1 | 11 | 33.1 | 1.594 | 11 | 36.91 | 2.602 |
| | M2 | 11 | 31.4 | 2.592 | 11 | 47.61 | 3.922 |
| | M3 | 11 | 33.8 | 2.574 | 11 | 58.51 | 2.067 |
| | M4 | 11 | 32.8 | 2.572 | 11 | 60.71 | 2.626 |
| F | 227.556 | | | | | | |
| df | 2.581 | | | | | | |
| Sig. | 0.000 | | | | | | |
| Partial Eta square | 0.770 | | | | | | |

The results of Table 7 show that the value of metacognition is significantly affected by metacognitive instructional strategies, *F* (2.581, 186.538) = 227.556, *p* = .000 < .05 at the *p* = 0.000 significance level, our null hypothesis H02 is rejected. It is concluded that metacognitive instructional strategies significantly affect Mc of students with varying abilities (above average, average, and below average students) of eighth graders in Mathematics. Furthermore, the partial Eta squared value (0.770) also supported the significant effect of metacognitive instructional strategies on the metacognition of students with varying abilities (above average, average, and below average) of eighth graders in Mathematics.

**Figure 2**

*Effect of cognitive instruction strategies on the metacognition of the experimental group and control group with variable abilities*

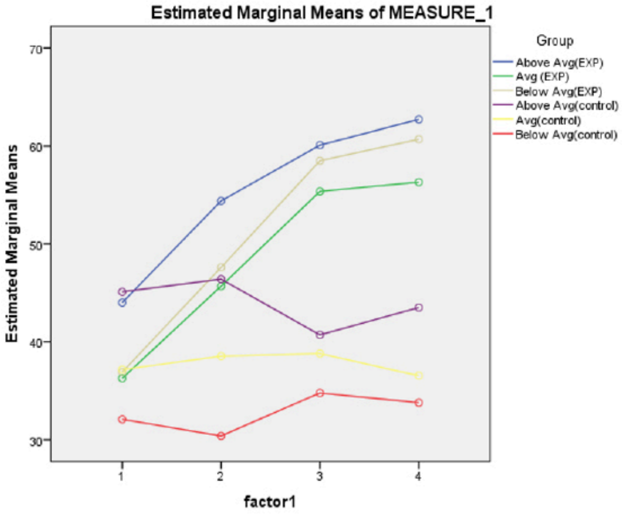


Figure 2 represents the metacognition of all subgroups of the experimental and control groups at different steps in a graphical form.

### Discussion

Figure 2 shows the changes in Mc of above-average, average, and below-average students of the experimental and control groups in different colours. In the experimental group, uniformity in the increase of Mc is observed in above-average and average students. In contrast, the graph of below-average shows rather a jump in Mc scores and outperforms even average students. Overall, the metacognitive teaching tactics used in the experimental group significantly increased Mc.

The above graph shows that there is no significant change in Mc scores of above-average, average, and below-average students of the control group. The Mc of the students was found to be positively impacted by metacognitive instructional tactics. These findings demonstrated that teaching using metacognitive instructional strategies can improve students' metacognitive ability. These findings likewise support the results of earlier investigations by Huff and Nietfeld (2009). The results of the above studies all pointed to students who were taught using metacognitive instructional methodologies with much more metacognition. The major goals of metacognitive teaching strategies are to help students recognise and stimulate their thought processes, which in turn helps people improve their metacognition (Mc) (Ozsoy & Ataman, 2009). Since Mc involves reflecting on one's thought process, Amjad and Tabasam (2024) suggested meta-level instructions rather than performance.

Metacognition of average and below-average students was examined before and after all three intervention steps to explore differences in the effects of metacognitive instructional tactics in above-average and below-average students. Generally speaking, after receiving an intervention, all groups show a significant growth in their levels of metacognition. After all intervention measures, students in the above-average group still demonstrate the highest levels of Mc, while those in the below-average group exhibit an astonishingly large increase.

After completing the first step of the intervention, these children even outperformed the average group of students. However, the average students also improved, but the below-average pupils exceeded their Mc level. These findings support earlier research (Pennequin et al., 2010; Iqbal et al., 2016). Metacognitive instructional techniques allowed low achievers to access such a comfortable classroom environment where they could learn to reflect on their deficiencies. This awareness also helps pupils to strengthen their ability to control cognition for efficient learning (Cardelle-Elawar,1995). The surprising achievement of metacognitive training techniques on lower achievers to improve students' metacognition motivates them to utilise such tactics in teaching-learning.

As Schraw (1998) suggested, raising awareness of Mc's existence and importance in academic achievement is the first step to stimulating it. Then comes the ability to employ effective tactics and, perhaps most importantly, awareness regarding when and where to use them. In conclusion, metacognitive instructional strategies greatly impact how well eighth graders at all levels (above average, average, and below average) can solve mathematical and MC problems. Metacognitive instructional tactics help students accelerate their ventures to improve their self-instructional skills.

### Recommendations

Metacognitive teaching strategies should be introduced to increase mathematics teachers' knowledge of Mc. Metacognitive instructional methodologies greatly improve the mathematics problem-solving abilities of students who perform below average. To strengthen the weak areas of grade 8 mathematics, it is recommended that the curriculum be expanded to include specific metacognitive teaching tactics such as self-questioning, modelling, thinking aloud, cooperative learning, and scaffolding. In the current study, Mc was only assessed using a metacognitive awareness inventory. Future research should triangulate the data to validate it using student interviews, think-aloud activities, and observational techniques in the classroom while students solve mathematical problems. It is encouraged to do an experimental study to examine the effectiveness of different metacognitive instructional strategies to assist students in developing their Mc and mathematical problem-solving skills.

## Declarations and Conflicts of Interest

### *Research Ethics Statement*

The Research Ethics Committee of The University of Lahore, Pakistan, has approved this study.

### *Consent for Publication Statement*

Not applicable to this paper

### *Conflict of Interest Statement*

The researchers have no conflict of interest over authorship ranking and publication of this paper.

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