

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

Musarrat Habib^a, Amjad Islam Amjad^b, Sarfraz Aslam^{c*}, Zahra Saleem^d, Atif Saleem^e

Received : 24 February 2024
Revised : 21 October 2024
Accepted : 26 December 2024
DOI : 10.26822/iejee.2024.368

^a Musarrat Habib, Department of Education, The University of Lahore, Lahore, 54950, Pakistan.
E-mail: musarrat.javaaid@ed.uol.edu.pk
ORCID: <https://orcid.org/0009-0009-7016-3837>

^b Amjad Islam Amjad, School Education Department, Government of Punjab, Kasur, Pakistan.
E-mail: amjad_14@yahoo.com
ORCID: <https://orcid.org/0000-0002-4250-7526>

^{c*} **Corresponding Author:** Sarfraz Aslam, Faculty of Education and Humanities, UNITAR International University, Petaling Jaya, Malaysia.
E-mail: sarfraz.aslam@unitar
ORCID: <https://orcid.org/0000-0001-7414-7572>

^d Zahra Saleem, Islamia University of Bahawalpur
E-mail: zahra.saleem@iub.edu.pk
ORCID: <https://orcid.org/0009-0005-3064-7416>

^e Atif Saleem, School of Education, University of Limerick, V94 T9PX Limerick, Ireland.
E-mail: Atif.Saleem@ul.ie
ORCID: <https://orcid.org/0000-0002-7595-842X>

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).



Copyright ©
www.iejee.com
ISSN: 1307-9298

© 2024 Published by KURA Education & Publishing. This is an open access article under the CC BY- NC- ND license. (<https://creativecommons.org/licenses/by/4.0/>)

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.

H₀₁: 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.

H₀₂: 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 (ϵ) 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

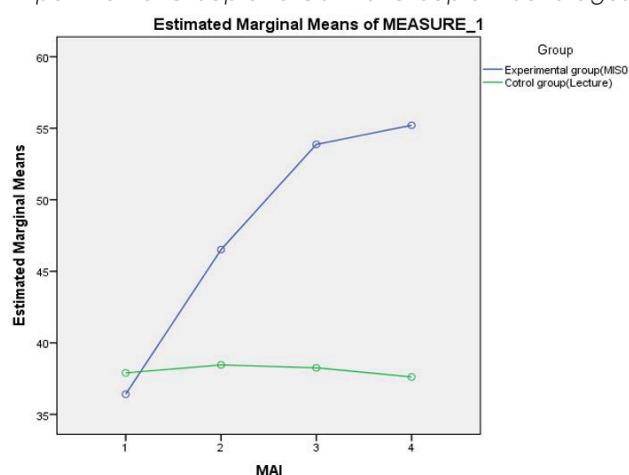
	Control			Experimental		
	N	Mean	SD	N	Mean	SD
M1 Pre-intervention	38	37.80	5.655	38	36.42	6.133
M2 Post-intervention Stage 1	38	38.47	6.522	38	46.52	6.202
M3 Post-intervention Stage 2	38	38.25	3.624	38	53.86	6.713
M4 Post-intervention Stage 3	38	37.52	4.602	38	55.23	7.848
F	162.292					
Df	2.332					
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 8th 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 H_{02} 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

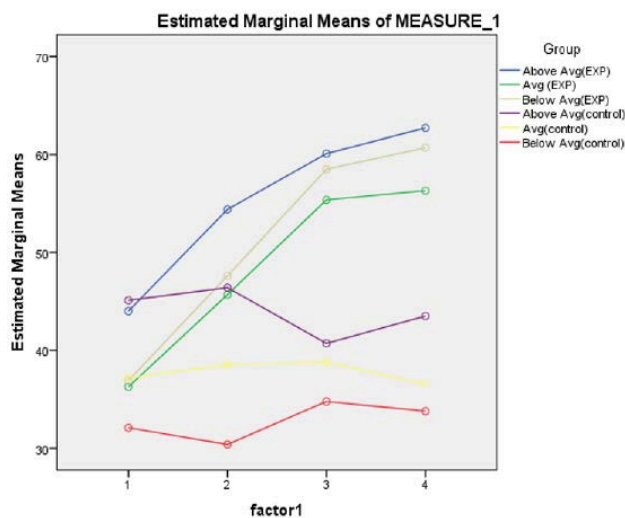


Figure 2 represents the metacognition of all subgroups of the experimental and control groups at different steps in a graphical form.

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.

References

- Akram, H., Al-Adwan, A. S., Aslam, S., & Khan, M. I. (2023). Pedagogical practices and challenges in cultivating moral values: A qualitative study of primary school teachers in Pakistan. *Education* 3-13, 51(4), 607-619. <https://doi.org/10.1080/03004279.2021.1992471>
- Amjad, A. I., & Tabbasam, U. (2024). Effect of Brain-Based Learning on Students' Extrinsic Motivation to Learn Mathematics: Introducing Neuroscience to Schools. *Journal of Sustainable Education* 1(1), 1-12. <https://journals.uol.edu.pk/jse/article/view/2617>
- Amjad, A. I., Habib, M., & Saeed, M. (2022b). Effect of brain-based learning on students' mathematics performance at the elementary level. *Pakistan Journal of Social Research*, 4(03), 38-51. <https://doi.org/10.52567/pjsr.v4i03.684>
- Amjad, A. I., Habib, M., Tabbasam, U., Alvi, G. F., Taseer, N. A., & Noreen, I. (2023). The impact of brain-based learning on students' intrinsic motivation to learn and perform in mathematics: A neuroscientific study in school psychology. *International Electronic Journal of Elementary Education*, 16(1), 111-122. <https://doi.org/10.26822/iejee.2023.318>
- Amjad, A. I., Tabbasam, U., & Abbas, N. (2022a). The effect of brain-based learning on students' self-efficacy to learn and perform mathematics: Implication of Neuroscience into school psychology. *Pakistan Languages and Humanities Review*, 6(3), 683-695. [http://doi.org/10.47205/plhr.2022\(6-III\)60](http://doi.org/10.47205/plhr.2022(6-III)60)
- Amjad, A. I., Tabbasam, U., & Ara, N. (2022). Neuroscientific study on the effect of brain-based learning on students' intrinsic motivation to learn mathematics. *Annals of Human and Social Sciences*, 3(2), 728-742. [https://doi.org/10.35484/ahss.2022\(3-II\)69](https://doi.org/10.35484/ahss.2022(3-II)69)
- Aslam, S., Saleem, A., Hali, A. U., & Zhang, B. (2021). Promoting sustainable development in school classrooms: Using reciprocal teaching in mathematics education. *TEM Journal*, 10(1), 392-400. <https://doi.org/10.18421/TEM101-49>
- Aydin, U., & Ubuz, B. (2010). Turkish version of the junior metacognitive awareness inventory: The validation study. *Education and Science*, 35(157), 30-45.
- Baker, L., & Beall, L. C. (2014). Metacognitive processes and reading comprehension. In *Handbook of Research on Reading Comprehension* (pp. 397-412). Routledge. <https://doi.org/10.4324/9781315759609-30>
- Barcikowski, R. S., & Robey, R. R. (1984). Decisions in single group repeated measures analysis: Statistical tests and three computer packages. *The American Statistician*, 38(2), 148-150. <https://doi.org/10.1080/00031305.1984.10483187>
- Brown, A. L. (1982). Learning how to learn from reading. *Reader meets author: Bridging the Gap*, 26-54.
- Brown, A. L. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. *Metacognition, Motivation, and Understanding*, 65-116.
- Cardelle-Elawar, M. (1995). Effects of metacognitive instruction on low achievers in mathematics problems. *Teaching and Teacher Education*, 11(1), 81-95. [https://doi.org/10.1016/0742-051X\(94\)00019-3](https://doi.org/10.1016/0742-051X(94)00019-3)
- De-Jager, B., Jansen, M., & Reezeit, G. (2005). The development of metacognition in primary school learning environments. *School Effectiveness and School Improvement*, 16(2), 179-196. <https://doi.org/10.1080/09243450500114181>

- Desoete, A., & De-Craene, B. (2019). Metacognition and mathematics education: An overview. *ZDM*, 51, 565-575. <https://doi.org/10.1007/s11858-019-01060-w>
- Dignath, C., Buettner, G., & Langfeldt, H. P. (2008). How can primary school students learn self-regulated learning strategies most effectively? A meta-analysis on self-regulation training programmes. *Educational Research Review*, 3(2), 101-129. <https://doi.org/10.1016/j.edurev.2008.02.003>
- Dörr, L., & Perels, F. (2019). Improving metacognitive abilities as an important prerequisite for self-regulated learning in preschool children. *International Electronic Journal of Elementary Education*, 11(5), 449-459. <https://doi.org/10.26822/iejee.2019553341>
- Ellah, B. O., Oche Omaikwu, S., Obinne, A. D. E., & Adikwu, O. (2023). Development and Factorial Validation of Meta-Cognitive Awareness Inventory in Physics (MAIP) for Senior Secondary Students in Benue State, Nigeria. *Journal of Research in Science and Mathematics Education (J-RSME)*, 2(1), 1-12. <https://doi.org/10.56855/jrsme.v2i1.174>
- Elosegi, P., Rahnev, D., & Soto, D. (2024). Think twice: Re-assessing confidence improves visual metacognition. *Attention, Perception, & Psychophysics*, 86(2), 373-380. <https://doi.org/10.3758/s13414-023-02823-0>
- Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, 34(10), 906-911. <https://doi.org/10.1037/0003-066X.34.10.906>
- Gama, C. A. (2005). *Integrating metacognition instruction in interactive learning environments* (Doctoral dissertation, University of Sussex).
- Girden, E. (1992). ANOVA. 2455 Teller Road, Thousand Oaks, California 91320 United States of America. *SAGE Publications, Inc.* <https://doi.org/10.4135/9781412983419>
- Habib, M., & Rana, R. A. (2020). Exploring 8th graders' metacognition and its relationship with mathematical academic achievement. *Pakistan Journal of Education*, 37(1), 61-74. <https://doi.org/10.30971/pje.v37i1.1053>
- Hacker, D. J., & Dunlosky, J. (2003). Not All Metacognition Is Created Equal. *New Directions for Teaching and Learning*, 95(1), 73-79. <https://doi.org/10.1002/tl.116>
- Huff, J. D., & Nietfeld, J. L. (2009). Using strategy instruction and confidence judgments to improve metacognitive monitoring. *Metacognition and Learning*, 4(2), 161-176. <https://doi.org/10.1007/s11409-009-9042-8>
- Huynh, H., & Feldt, L. S. (1976). Estimation of the Box correction for degrees of freedom from sample data in randomised block and split-plot designs. *Journal of Educational Statistics*, 1(1), 69-82. <https://doi.org/10.2307/1164736>
- Jacobs, J. E., & Paris, S. G. (1987). Children's metacognition about reading: Issues in definition, measurement, and instruction. *Educational Psychologist*, 22(3-4), 255-278. <https://doi.org/10.1080/00461520.1987.9653052>
- Kirbulut, Z. D. (2014). Modeling the Relationship between High School Students' Chemistry Self-Efficacy and Metacognitive Awareness. *International Journal of Environmental and Science Education*, 9(2), 177-196.
- Kramarski, B., & Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: The effects of cooperative learning and metacognitive training. *American Educational Research Journal*, 40(1), 281-310. <https://doi.org/10.3102/00028312040001281>
- Livingston, J. A. (2003). Metacognition: An overview. (ERIC Document Reproduction Service No. ED474273). *Education Resources Information Center*.
- McCormick, C. C., Dimmat, C., & Sullivan, F. R. (2013). Metacognition, Learning and Instruction: In Willima M. Reynolds, Gloria E. Miller, Irving B. Weiner (Ed.), *Handbook of Psychology* (pp.69-97). NJ: Wiley & Sons, Inc. <https://doi.org/10.1002/9781118133880.hop207004>
- Myers, M., & Paris, S. G. (1978). Children's metacognitive knowledge about reading. *Journal of Educational Psychology*, 70(5), 680.-690. <https://doi.org/10.1037/0022-0663.70.5.680>
- Otani, H., & Widner, R. L. (2005). Metacognition: New Issues and Approaches Guest Editors' Introduction. *The Journal of General Psychology*, 132(4), 329-334. <https://doi.org/10.3200/GENP132.4.329-334>

- Ozsoy, G., & Ataman, A. (2009). The effect of metacognitive strategy training on mathematical problem-solving achievement. *International Electronic Journal of Elementary Education*, 1(2), 67-82.
- Ozturk, N. (2022). A pedagogy of metacognition for reading classrooms. *International Journal of Education and Literacy Studies*, 10(1), 162-172. <https://doi.org/10.7575/aiac.ijels.v10n.1p.162>
- Panaoura, A., & Philippou, G. (2005). The measurement of young pupils' metacognitive ability in mathematics: The case of self-representation and self-evaluation. In *Proceedings of Cerme*, 4, 1-10.
- Pennequin, V., Sorel, O., Nanty, I., & Fontaine, R. (2010). Metacognition and low achievement in mathematics: The effect of training in the use of metacognitive skills to solve mathematical word problems. *Thinking & Reasoning*, 16(3), 198-220. <https://doi.org/10.1080/13546783.2010.509052>
- Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice*, 41(4), 219-225. https://doi.org/10.1207/s15430421tip4104_3
- Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science*, 26(1), 113-125. <https://doi.org/10.1023/A:1003044231033>
- Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, 19(4), 460-475. <https://doi.org/10.1006/ceps.1994.1033>
- Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in Science Education*, 36(1), 111-139. <https://doi.org/10.1007/s11165-005-3917-8>
- Sperling, R. A., Howard, B. C., Miller, L. A., & Murphy, C. (2002). Measures of children's knowledge and regulation of cognition. *Contemporary Educational Psychology*, 27(1), 51-79. <https://doi.org/10.1006/ceps.2001.1091>
- Sungur, S. (2007). Contribution of motivational beliefs and metacognition to students' performance under consequential and nonconsequential test conditions. *Educational Research and Evaluation*, 13(2), 127-142. <https://doi.org/10.1080/13803610701234898>
- Veenman, M. V., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences*, 15(2), 159-176. <https://doi.org/10.1016/j.lindif.2004.12.001>
- Veenman, M. V., & van Cleef, D. (2019). Measuring metacognitive skills for mathematics: students' self-reports versus on-line assessment methods. *ZDM*, 51(4), 691-701. <https://doi.org/10.1007/s11858-018-1006-5>
- Veenman, M. V., Wilhelm, P., & Beishuizen, J. J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. *Learning and Instruction*, 14(1), 89-109. <https://doi.org/10.1016/j.learninstruc.2003.10.004>