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# Assessing the Role of Metacognition in Mathematics Education for Female Students: empirical Evidence from Pakistan

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## ABSTRACT
*Reasoning has become an essential tool for all students to cope with challenges of the modern world. Therefore, to foster the reasoning among the students, the teachers should use effective strategies in the teaching process. The present experimental study aims to assess the effect of metacognitive strategies for mathematical reasoning in female students. Pre-test post-test control group design was adopted in the study. The participants were 44 female students: 21 in the control and 23 in the experimental group. A valid and reliable research instrument; mathematical reasoning test was adopted for the study. A pretest and a posttest were conducted for participants of the control group and the experimental group before and after the intervention. An independent samples t-test was applied to compare the mean scores. A significant difference was found between the mean scores of both groups. The students in the experimental group obtained greater score as compared to the students in the control group in the post-test. It has been concluded that metacognition has enhanced mathematical reasoning for female students at secondary level.*
***Keywords:*** *STEM, Critical Thinking, Female Students, Self-regulation, Mathematical Reasoning*

## INTRODUCTION
In science, technology, engineering, and mathematics (STEM)education, metacognition is considered an effective strategy for the teaching and learning of mathematics. It has become a topic of interest in STEM education research and practices (Kladchuen & Srisomphan, 2021). Metacognition can be seen as humans' mental ability to monitor and control. In simple words, metacognition is an ability to know about knowing (Johnson et al., 2022). It has been proved that metacognitive teaching and learning strategies have a positive effect on the construction of new knowledge. Metacognitive strategies also support the development of mathematical and scientific skills (Mevarech & Fridkin, 2006; Suparma et al., 2021).

In mathematical skills, mathematical reasoning is considered as a higher-order thinking skill (Zengin & Erdem, 2024). Mathematical reasoning supports the students to apply other mathematical skills in schools and out of schools (Andersson et al., 2022; Khasawneh et al., 2023; Kircali & Ozdener, 2022; Manurung et al., 2022). Being a critical skill, mathematical reasoning enables students to analyze mathematical situations and logical arguments (Girelli, 2022; Kocyigit & Yenilmez, 2022; Kurniawan et al., 2022; Negara et al., 2022). Mathematical and scientific reasoning also ensure students' better academic achievement in mathematics, science and other subjects. It enables students to solve problems in daily life activities. The development of reasoning needs creative teaching and learning strategies (Albaqawi, 2023; kusharyadi & Junadi, 2023; Mastuti et al., 2022; Jader et al., 2020).

The traditional and teacher-centered teaching strategies are not suitable for the development of reasoning. In all developed countries, effective teaching and learning strategies are used for the teaching of STEM. Among the effective teaching strategies, metacognition is considered as a most effective teaching and learning strategy. Developing and underdeveloped countries should also apply metacognitive strategies in the teaching and learning process. Applications of metacognitive strategies enable students to perform better in all subjects (Angraini et al., 2023; Brodie, 2010).

In most of the developing and underdeveloped countries, mathematical problems are solved with scamming of ideas and concepts. Scamming of ideas is not supportive for the development of higher-order thinking

skills like mathematical and scientific reasoning. Therefore, effective teaching and learning strategies should be used to develop reasoning among the students (Abidin et al., 2020; Deeba & Hafeez, 2021). Pakistan is also a developing country, which demands skilled students. With the application of metacognitive strategies, Pakistani students can also become skilled force. The researcher delimited the area of STEM and intended to conduct the study only on mathematics education. Therefore, present study assessed the effect of metacognition on secondary students' mathematical reasoning for female students.

**Objectives of the study**

The objective of the study was to assess the effect of metacognition on mathematical reasoning among female secondary school students.

**Hypothesis**

A null hypothesis was framed to obtain the objective of the study. The null hypothesis is stated below:

$\boldsymbol{Ho1}$

There is no significant mean difference of pretest of the control and the experimental group.

$\boldsymbol{Ho2}$

There is no significant difference in the means scores of the control and the experimental group

**LITERATURE REVIEW**

Mathematics is a useful subject for the prosperity of all individuals, societies, nations and countries. Mathematical content is mainly distributed into three areas: Arithmetic, algebra and geometry (Mustafa, 2011; Sidhu, 2018). These all areas of mathematics are useful for humanity; as the application of these areas enables other subjects useful for humanity. In the present study, only one area of mathematics; arithmetic is considered. Metacognition is a regulatory system that helps individuals to control their cognitive process. It enables students to comprehend mathematical idea and to apply them accurately. Momentarily, metacognition is referred to as thinking about thinking (Brehmer et al., 2016; Polya, 2007; Kutluca & Tum, 2021). Students use different metacognitive strategies as useful approaches for the solution of the mathematical problems with reasoning.

Among the metacognitive strategies, self-planning, self-monitoring, self-evaluation, and think aloud are used as effective strategies for the teaching learning process. These strategies are considered as brainstorming strategies for the students (Bray, 2013; Kramarski, 2008). In the think-aloud strategy, students articulate their mathematical ideas during the solution of mathematical problems. In planning strategy, students plan how to complete their tasks. In the next phase, the students monitor their activities to complete the tasks and view the progress of their activities. In the evaluation strategy, the students evaluate the effectiveness of their strategies to complete the tasks (Jonsson et al., 2022; Lestari, 2019). Different researches have been conducted to assess the development of mathematical reasoning through metacognition in different developed countries (Ozdemir et al., 2023; Rizos & Gkrekas, 2023; Ulinnuha et al., 2021).

Kramarski and Mevarech (2003) conducted experimental research in collaborative settings for the experimental group to find the development of mathematical reasoning through metacognition. Their study was experimental and collaborative settings were arranged for the intervention. Metacognitive strategies were used as an intervention for the participants of the experimental group. The findings of the study showed a significant positive effect on the students' mathematical reasoning. Clarke & Sullivan (2012) also conducted experimental research to assess the effect of metacognition on students' mathematical reasoning. They found that after getting the metacognitive training, the students performed well and got more score in the test of mathematical reasoning. Lestari and Jailani (2018) also conducted an experimental study to find the development of mathematical reasoning through metacognition. They also found that metacognition developed mathematical reasoning among secondary students.

In addition to the studies conducted in the developed countries, Ullah and Akbar (2020) conducted an experimental study in a developing country, Pakistan to assess the effect of metacognition on mathematical reasoning. They found that metacognitive strategies enhance mathematical reasoning among high school students. Ullah and Akbar (2021) also conducted a study to assess the effectiveness of metacognitive

strategies for the development of mathematical deductive reasoning among secondary students. They also found a significant positive effect of metacognition on mathematical reasoning among the students. The participants of these both studies were male students. The researcher induced to conduct the study to assess the development of mathematical reasoning through metacognition among female students at secondary school level.

**METHODOLOGY AND DESIGN OF THE STUDY**

The study was experimental in nature and quasi experimental design was employed. A quantitative approach was used to collect the data. The pretest posttest nonequivalent control group design was selected for experiment. The data were in the form of participants' marks obtained in mathematical reasoning test (MRT). MRT was a valid and reliable research instrument developed by Ullah (2020). It was considered suitable for the study; as it was developed and applied in the in local context.

The study was conducted in a government girls' high school. Female students studying in grade 9 in the government girls' high school were taken as participants of the study. Average age of the participants was 14 years. Two sections of grade 9 were taken as intact groups for the study. These sections were randomly divided into the control and the experimental group.

The control group was taught by traditional teaching strategy and the experimental group was taught with metacognitive strategy. The intervention lasted for the period of 12 weeks. The intervention to the experimental group was given using metacognitive strategies. Metacognitive strategies were first modeled by the teacher in the teaching of mathematics to the experimental group. After that the participants of the experimental group applied these strategies in solving mathematical problems. The intervention to the experimental group was given in collaborative settings. The participants of the experimental group were divided into small groups. As discussed earlier, think aloud, self-planning, monitoring and evaluation strategies were used as teaching strategy for the experimental group.

**FINDINGS**

The data obtained from the pre-test and the post-test were analyzed statistically. Before running a test, nature of the data was assessed. The data fulfilled the assumptions of independent samples t-test (IS t-test). Details of normality test have been given below in the table 1.

**Table 1** ***Shapirowilk test for normality of data***

| Test | Group | N | Statistics | Significance |
|---|---|---|---|---|
| Pre-test | Control | 21 | 0.939 | 0.206 |
| | Experimental | 23 | 0.969 | 0.663 |
| Post-test | Control | 21 | 0.938 | 0.201 |
| | Experimental | 23 | 0.956 | 0.395 |

The data fulfilled the assumptions of normality and homogeneity of variance. Therefore, IS t-test was run using a computer software, SPSS (Statistical Packages for the Social Sciences). The test was applied on pre-test and post-test score of the control and the experimental group.

The results of the data analysis have been presented in the following tables.

**Table 2.** ***Independent Samples t-test for pre and post-test***

| *Test* | *Group* | *N* | *M* | *SD* | *T* | *df* | *Sig.(2-tailed)* |
|---|---|---|---|---|---|---|---|
| Pre | Control | 21 | 44.524 | 8.334 | 1.918 | 42 | 0.062 |
| | Experiment | 23 | 39.913 | 7.615 | | | |
| Post | Control | 21 | 64.000 | 5.882 | -35.389 | 42 | 0.000 |
| | Experiment | 23 | 113.130 | 2.989 | | | |

The table 2 illustrates the results of independent samples t-test. It shows a comparison between mean scores of the control and the experimental groups in pre-test and the post-test. Results of pre-test describes that the mean score of the control group (Mean= 44.524 and SD=8.334) and the mean score and standard deviation score (M=39.913 and SD=7.615) for t(42) = 1918, and P(t-tailed) =.062.

It shows that there is no significant difference between the mean scores of the control and the experimental group as P>.005. It indicates that before starting the intervention, both the groups were nearly at the same level. The null hypothesis 1 was accepted as there was no significant difference between mean scores of the control group and the experimental group.

The results of post-test shows that the means score and standard deviation of the control group (M= 64.000and SD=5.882), for t(42) =35.389, and P(2-tailed) =.000.

The results indicate a significant difference between mean scores of the control and the experimental group. Therefore, the null hypothesis 2 was rejected. It reveals a significant difference between means cores of the control and the experimental group.

## DISCUSSION

The study has proved the development of mathematical reasoning among female secondary school students through metacognition. The findings of the study supported the findings of previous studies. The study confirmed the findings of the study of Kramarski and Mevarekh (2003), Ullah and Akbar (2020).

The content of mathematics was same for the control and the experimental group. It indicated that teacher's teaching strategy for the experimental group play a vital role for the development of mathematical reasoning. Mathematical reasoning is a creative and critical thinking skill, which needs teacher's special teaching strategy to be developed among the students. In the present study teacher's role was to train the students in metacognitive strategies in teaching and learning process of mathematics. The classroom activities done by the students under guidance of the teacher also play a role for the development of mathematical reasoning, as the literature also reveals its development (Sumarmo & Nishitani, 2010; Ullah & Akbar, 2021). Cognitive psychology reveals that students can improve the performance in mathematics if they are involved in mathematical discourses. The present study was conducted in collaborative settings. The collaborative settings enable students to develop mathematical reasoning under their teacher's guidance. The students discuss the concepts and constructs with their peer students and teachers. This strategy helps the students to learn from each other and the teacher, which result in the development of creative and critical thinking skill i.e. mathematical reasoning among the students (Kornell & Metcalfe, 2006; Schraw & Gutierrez, 2017).

## CONCLUSION

The findings of the study reveal no significant difference between the means cores of the control and the experimental group in pre-test. It shows initially both the groups were nearly at the same level. After completing the intervention, a post-test was conducted for both the groups. The findings of the study reveal a significant difference between means cores of the groups. The participants of the experimental groups outperformed than the participants of the control group. On the basis of the findings of the study, it can be concluded that metacognitive strategies enhance mathematical reasoning among female secondary students. The study has proved the development of mathematical reasoning among female secondary students in Pakistani context. Therefore, metacognitive strategies may be used by the teachers and the students at secondary level in the teaching and learning of mathematics.

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