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# Effect of Use of Metacognitive Strategies on Adaptive Reasoning, Procedural Fluency and Connections of Mathematics with Other Subjects of Fourth Graders with Dyscalculia

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**Abstract**

The study with 28 students having dyscalculia utilized pre-test post-test control group design. The experimental group was given remediation by use of metacognitive strategies while control group was taught through traditional method. Findings revealed that the subjects in metacognitive strategies group showed significant improvement from pre test to post test in mathematical skills (Adaptive reasoning, Procedural fluency and connections of mathematics with other subjects).

**Keywords:** Metacognitive strategies, adaptive reasoning, procedural fluency, connections of mathematics with other subjects, dyscalculia.

## Introduction

In schools, teacher comes across certain children who have diverse learning abilities and special learning needs. Some of the learners achieve high and some may lag behind in their learning. Most students have problems in school at one time or other. Some children, despite being normal have difficulty in learning or remembering the school subjects. The difficulty in learning is observed mostly in academic areas such as reading, writing or academic. This inability might be the result of a learning disability.

Disorders like reading and writing disabilities, arithmetic disabilities etc. are either ignored or not understood and the children suffer for no fault of theirs. Children with learning disabilities are low achievers and they are found to be unable to cope with the school work. Different kinds of learning disabilities can be found among such school children and there may be a great deal of variation between these individuals. These individuals find it difficult to learn without special attention. Children with such problems may be slow learners, average learners or even gifted ones. Also they may have normal hearing and vision. But they may lack the ability to acquire the basic academic skills. These children are ignored in the classroom due to lack of skills and may be often considered to be lazy, inattentive or stupid by their teachers.

The difficulties that children face in the learning process have begun to attract serious attention. It has become a real educational handicap and a widespread issue in today's society. It is a great challenge on the part of teachers and trained educational specialists to deal with those children with learning disorders through the use of innovative educational strategies (Raja & Kumar, 2013).

In order to solve everyday problems in mathematics, it is necessary to use many skills that include a set of rules and algorithms (Ramaa & Gowramma, 2002). Moreover, formal education, daily living activities and jobs require knowledge and application skills of counting and simple mathematical operations related to addition, subtraction, multiplication and division (Floyd, Evans & McGrew, 2003). Problems with mathematics start in primary school and persist till adulthood (Bojanin, 2002). Considering the fact that mathematics is hierarchical, students who did not understand the previous material will, in addition to their problems in basic mathematics, also experience failure that may eventuate to mathematical anxiety (Miller & Mercer, 1997). These combined difficulties appear in the clinical form called dyscalculia which is a set of specific difficulties in learning mathematics and in performing mathematical tasks in children with normal intelligence, access to education and without severe psychological problems (Bojanin, 2002).

Various studies found different incidence. Lewis, Hitch and Walker (1994) found prevalence of dyscalculia of 1.3% among children aged 9-10 years. Studies of Kosc (1974), Badian (1983), Gowramma (2000), Shalev and Gross-Tsur (2001), Koumoula, Tsironi, Stamouli, Bardani, Siapati and Graham (2004), Guillemot (2010) and showed that the prevalence of developmental dyscalculia in these countries is about 3 to 6.5%. Geary (2006) investigated Characteristics and Potential Influence of dyscalculia at an Early Age. Between 3 and 8% of school-aged children will show evidence of dyscalculia.

However, Ostad (1999), Shalev (2004), Barbaresi, Katusic, Colligan, Weaver and Jacobsen (2005), and Jovanović, Jovanović, Banković-Gajić, Nikolić, Svetozarević and Ignjatović-Ristić (2013) found that incidence of dyscalculia by varying from a low of 5.9% to a high of 13.8% depending on the mathematics learning disorder definition. The general opinion is that boys do mathematics better than girls (Ardila & Rosselli, 2002). In many epidemiological studies, the researchers found a higher incidence of mathematical difficulties among boys (Share, Moffitt & Silva, 1988; Badian, 1983; Von Aster, 2000; Barbaresi, Katusic, Colligan, Weaver & Jacobsen, 2005). However, most prevalence studies of developmental dyscalculia point to equal rates between the sexes (Shalev, Manor, Kerem, Ayali, Badichi, Friedlander & Gross-Tsur, 2001; Lewis, Hitch & Walker, 1994).

Jha (2012) attempted to disclose the fundamental reasons of students' poor achievement in mathematics through analysis of the levels of their abilities using Newman Procedure. The data recommended that most of students' errors occurred at comprehension as well as at the transformation level. Good achievers and fair achievers did not make mistake at reading level, but poor achievers errors are observed at reading level and mostly at comprehension level.

Beygi, Padakannaya and Gowramma (2010) investigated the impact of remedial intervention on students' performance with dyscalculia in teaching addition and subtraction. Forty male students with dyscalculia (20 in experimental, and 20 in control groups) from fourth and fifth grades in Arak, Iran were the participants. The experimental group received remedial program in addition to their regular classroom teaching (every other day). Data analysis indicated a significant increase in the subtraction and addition performance after remedial intervention.

Chauhan (2004) investigated the effectiveness of different strategies for remediating dyscalculia in primary school children. She used three different kinds of remedial treatments i.e. cooperative learning, clinical mathematics interview and error detection and correction (error analysis). Sample contained 84 students in three experimental and one control group. Descriptive statistics like mean and standard deviation and inferential statistics ANOVA and t-test has been used for describing and inference of the data. Results shown that cooperative learning, clinical mathematics interview and error detection and correction, all the three strategies contribute significantly for the remediation of dyscalculia for grade 2 and 3 students. Grade 2 students have improved more than grade 3 students.

Shih (2005) investigated effects of number sense intervention on second-grade students with mathematics learning disabilities. The purposes of this study were to investigate the effectiveness of number sense instruction on fact retrieval performance of students with math learning disabilities & to examine whether students with math learning disabilities who receive instruction in number sense can generalize their understanding of number and number systems to untaught math skills. The results showed that students who received repeated practice followed by number sense instruction had better initial performance on fact retrieval.

Ramaa and Gowramma (2002) described the procedures adopted by two independent studies in India for identifying and classifying children with dyscalculia in primary schools. For determining the presence of dyscalculia both inclusionary and exclusionary criteria were used. When other possible causes of arithmetic failure had been excluded, figures for dyscalculia came out as 5.98% (15 cases out of 251) in one study and 5.54% (78 out of 1408) in the second. It was found in the latter study that 40 out of the 78 (51.27%) also had reading and writing problems.

Rozario and Kapur (1992) used intervention strategies to remediate problems in four basic operations progressing from concrete level to abstract level. Results indicated that there was a significant improvement in the performance of arithmetic tests after remedial education.

Ramaa (1990) revealed that difficulty of the students with dyscalculia in concrete situations would definitely influence their performance in tasks dealing with numbers which are relatively most abstract.

Dyscalculia is the result of specific disabilities in basic numerical processing, rather than the consequence of deficits in other cognitive abilities. Educational interventions for dyscalculia range from rote learning of arithmetic facts to developing strategies for solving arithmetic exercise. It can be remediated with different strategies and showed significant improvement.

It is possible that the difficulties faced by dyscalculic pupils' stems from the lack of an intuitive grasp of number. The defective 'number module' hypothesis postulates a developing brain has a specialised capacity (number module) for recognising and mentally manipulating numerosities (cardinal values). This is probably hardwired into the brain, and in dyscalculia is thought not to develop normally. Evidence is found in the slower performance of dyscalculics in subitizing and numerical magnitude tasks.

Landerl, Bevan and Butterworth (2003, p.106) claimed that 'the underlying cause of dyscalculia is likely to be related to dysfunction of this system'. Piazza and Dehaene 2004, p.3) stated: 'An elementary number system is present very early in life in both humans and animals, and constitutes the start - up tool for the development of symbolic numerical thinking that permeates our western technological societies'. Recent research by Piazza, Pinel, Le Bihan and Dehaene (2007) has shown that this region is activated in response to numbers, presented as either a pattern of dots or as Arabic numerals, and further, that this region processes numerical information. Their findings demonstrated that the two hemispheres of the parietal lobe act differently in processing numbers. It is the left lobe that contains abstract numerical representations, but the right lobe shows a dependence on the notation used, either as Arabic numerals or as words. Similarly, Cohen Kadosh, Cohen Kadosh and Kaas (2007) found numerical representations, which are notation - dependent, in the right parietal lobe.

Faust, Ashcraft and Fleck (1996) outlined that mathematical tasks could cause high levels of anxiety particular to mathematics rather than to any other given difficult activity. Furthermore, Burns (1998) stated that over two thirds of adults felt anxious when taking up mathematical tasks. The performance of individuals with dyscalculia is highly affected by anxiety especially when this is at high levels. A study carried out by Rubinsten and Tannock (2010) with 23 participants illustrates that there is a direct link between performance and anxiety. Therefore, the level of anxiety "can actually rise to the point where it paralyses their [referring to dyscalculic learners] ability to perform even simple maths operations" (Emerson & Babtie 2010, p.9). When carrying out mathematical tasks one must concentrate, however, high levels of anxiety interrupts such needed concentration. Therefore, individuals who underachieve in mathematics may be a victim of stress (Henderson, Came& Brough, 2003).

## Objective

The objective of present paper is to examine whether children with dyscalculia will improve in adaptive reasoning, procedural fluency and connections of mathematics with other subjects when given remediation by metacognitive strategies.

Metacognitive Strategies and adaptive reasoning, procedural fluency and connections of mathematics with subjects: Review

Hypothesis 1: The children with dyscalculia will improve significantly in adaptive reasoning after administration of metacognitive strategies.

Metacognition and adaptive reasoning

Following is a brief account of studies related to metacognitive strategies and adaptive reasoning:

Safari & Meskini (2016) studied the effect of metacognitive instruction on problem solving skills. The findings of the posttest showed that the total mean scores of problem solving skills in the experimental and control groups were 151.90 and 101.65, respectively, indicating a significant difference between them ($p<0.001$). No significant difference, however, was found between the students' mean scores in terms of gender and major. Since metacognitive instruction has positive effects on students' problem solving skills and is required to enhance academic achievement, metacognitive strategies are recommended to be taught to the students.

Lai, Zhu, Chen and Li (2015) investigated the effects of mathematics anxiety and mathematical metacognition on mathematical learning difficulties. The results indicated that mathematical metacognition mediated the effect of MA on WPS after controlling for IQ. Second, they divided the children into four mathematics achievement groups including high achieving (HA), typical achieving (TA), low achieving (LA), and mathematical learning difficulty (MLD). Because mathematical metacognition and MA predicted mathematics achievement, we compared group differences in metacognition and MA with IQ partialled out. The results showed that children with MLD scored lower in self-image and higher in learning mathematics anxiety (LMA) than the TA and HA children, but not in mathematical evaluation anxiety (MEA). MLD children's LMA was also higher than that of their LA counterparts.

Harandi, Eslami, Sharbabaki, Ahmadi, Deh and Darehkordi (2013) assessed the effect of metacognitive strategy training on problem solving performance and social skills in high school girls. The results indicated that students in the Metacognitive treatment group significantly improved in both social skills and problem-solving performance.

Alikamar, Alamolhodaei and Radmehr (2013) conducted a study of the role of meta-cognition on the effect of working memory capacity on students' mathematical problem solving while considering different psychological factors. Results obtained indicate that metacognition had distinctive and challenging variable than other factors in use of WMC in mathematical problem solving. In other words, the correlation superiority between WMC and mathematical performance was found in group of high metacognition.

Babakhani (2011) studied the effect of teaching the cognitive and meta-cognitive strategies (self-instruction procedure) on verbal math problem-solving performance of primary school students with verbal problem- solving difficulties. The results of repeated measures analysis showed that teaching of cognitive and meta-cognitive strategies (self-instructional procedure) significantly improved performance of experimental group in both genders ($F=44.86$, $P<0.0001$) also no signified differences between boys and girls in either applying the strategies or effectiveness of teaching ($F=1.22$, $P>0.05$).

Bayat and Tarmizi (2010) assessed cognitive and metacognitive strategies during algebra problem solving among university students. The design adopted for this study was a descriptive correlation design. The results showed that there is no significant correlation between Algebra problem solving performance with shallow cognition strategy ($r = -.134$, $p>0.05$). Similarly, there is no significant relationship between the students' performance with deep cognitive strategy ($r = .124$, $p>0.05$). Specifically, there is significant relationship between overall performance in the course and all three subscales of meta-cognition (knowledge, planning and evaluation). In conclusion, meta-cognitive strategies may have impact on mathematical performance among university students whilst cognitive strategies indicated minimal impact.

Kyong-Eun (2009) examined the effectiveness of schema-based intervention on the word problem of mathematics in middle school students having learning difficulties in 6th and 7th grades. The findings provided empirical evidence that schema-based intervention was effective in teaching middle school students with learning disabilities to solve multiplication and division word problems.

Özsoya and Ataman (2009) investigated the effect of metacognitive strategy training on mathematical problem solving achievement. The results indicated that students in the metacognitive treatment group significantly improved in both mathematical problem solving achievement and metacognitive skills.

Analysis of review of studies by Safari & Meskini (2016), Lai, Zhu, Chen and Li (2015), Harandi, Sharbabaki, Deh and Darehkordi (2013), Alikamar, Alamolhodaei and Radmehr (2013), Babakhani (2011), Bayat and Tarmizi (2010), Kyong-Eun (2009), Özsoya and Ataman (2009) indicated that reasoning skills in mathematics has improved significantly by metacognition strategies. Various strategies were suggested by the researchers. Metacognitive strategies showed significant improvement in increasing achievement, motivation, metacognitive skills, attitude and permanence of mathematics among children with dyscalculia. So in the present study, researcher used metacognitive strategies for dyscalculic children for enhancing their reasoning.

Hypothesis 2: The children with dyscalculia will improve significantly in procedural fluency after administration of metacognitive strategies.

Metacognition strategies and procedural fluency

Following is a study related to metacognitive strategies and procedural fluency:

Laistner (2016) examined the effect of metacognition strategies on student achievement in mathematics. The result found that there was a significant difference in the scores of pre and post test, overall and with female participants.

Jbeili (2012) investigated the effect of cooperative learning with metacognitive scaffolding on mathematics conceptual understanding and procedural fluency in learning and solving problems and tasks involving the addition and subtraction of fractions. The results showed that students in group CLMS significantly outperformed students in groups CL and T in mathematics conceptual understanding and procedural fluency. The results also showed that students in group CL significantly outperformed their counterparts in group T in mathematics conceptual understanding and procedural fluency.

Kwang (2000) studied the effect of metacognitive training on the mathematical word problem solving of Singapore 11-12 year olds in a computer environment. The findings from the analysis of mathematical achievement test and think aloud protocol data reveal that metacognitive training results in improvement in mathematical word problem solving performance, and that lower achievers appear to show the full benefit from metacognitive training only after a period of time.

Analysis of review of studies by Laistner (2016), Jbeili (2012), Kwang (2000) indicated that procedural fluency in mathematics has improved significantly by metacognition strategies. Various strategies were suggested by the researchers. Metacognitive strategies showed significant improvement in increasing achievement, the addition and subtraction of fractions and mathematical word problem solving among children with dyscalculia. So in the present study, researcher used metacognitive strategies for dyscalculic children for enhancing their procedural fluency.

Hypothesis 3: The children with dyscalculia will improve significantly in making connections of mathematics with other subjects after administration of metacognitive strategies.

Metacognition and connections of mathematics with other subjects

Following is a study related to metacognitive strategies and connections of mathematics with other subjects: Alzahrani (2017) studied an exploration of the perceptions of a teacher and students in a secondary school through metacognition and its role in mathematics learning. The data produced essential finding based on thematic analysis techniques, regarding study's aim. Firstly, the traditional method can hinder mathematics teaching and learning through metacognition. Secondly, although metacognitive mathematics instruction should be planned, the strategy that is introduced should be directly targeted at improving the monitoring and regulation of students' thought when dealing with mathematics problems.

Şahin and Kendir (2013) studied the effect of using metacognitive strategies for solving geometry problems on students' achievement, metacognitive skills and attitude. Results showed that the students in the experimental group had developed a better attitude toward geometry and mathematics, which might be attributed to the improvement in their self-confidence. The improvement in their attitude toward geometry and mathematics led to a corresponding increase in their achievement.

Analysis of review of studies by Alzahrani (2017) and Şahin and Kendir (2013) indicated that metacognition strategies were effective for solving geometry problems on students' achievement, metacognitive skills and attitude.

Literature presented above is not exhaustive in nature. All the same, it has led to better understanding of variable involved. Therefore hypotheses are proposed based on above literature.

## Method

Design

An experimental design named pre test post test control group was used.

Sample

Out of 15, eight CBSE schools were randomly selected from Panchkula district. In first phase, report cards of 720 fourth graders were observed to check the discrepancy between the achievement of mathematics and languages. A list of 80 students who had discrepancy in the achievement of mathematics and languages was prepared by the researcher. In second phase, teacher referral forms were distributed to all class teachers of fourth grade students for listed students. On the basis of teacher referral forms 70 students were further observed for the characteristics of dyscalculia. Raven's Progressive Matrices was also administered just to eliminate low intelligence on 70 children identified in the second phase. In third phase, 68 students who got score of 23 and above in Raven's Progressive Matrices were selected. A score of 23 indicates average performance.

In next phase, Diagnostic test for mathematics disorders for fourth graders was administered on 68 students to confirm the specific mathematical disabilities among children. In this process the researcher identified 52 children with dyscalculia.

These 52 children were identified as dyscalculic children. In first stage of examining report cards, researcher shortlisted 80 students by observing discrepancy in scores of mathematics and languages. In second stage researcher used teacher referral forms and she identified 70 students out of 80 who had discrepancy in achievement of languages and mathematics. In last stage, research identified 52 students out of 70 on the basis of scores obtained from diagnostic test for mathematics disorders for fourth graders. The schools which had highest number of dyscalculic children were taken for experimental research. The subjects were divided into two groups viz. one experimental (metacognitive strategies) and one control group (traditional teaching).

Tools

Identifying tools

- Report cards

In the identification process, first step was to observe the report cards of the students. The students having a discrepancy of more than 25% in language and mathematics performance, with higher marks in language were shortlisted for further research.

- Teacher referral forms

The form was prepared and used by the researcher for identification of students with a risk of dyscalculia with the help of their class teacher's response. The researcher developed this referral form with the advice of experts. Researcher prepared two sections of the teacher referral form, one is prepared for the language teachers and another is meant for mathematics teachers.

- Coloured progressive matrices (CPM)

It is designed for children aged 5 through 11 years-of-age, the elderly, and mentally and physically impaired individuals. This tool was used for measuring intelligence. This tool is known for assessing the degree to which children can clearly think or the level to which their intellectual functions have deteriorated.

- Diagnostic test of Mathematical Disorder for Fourth Graders

This tool was constructed and standardized by researcher. It includes memory (long term and short term), number operation difficulties, and language processing difficulties, attention deficits, visual problems, closure and generalization. This tool was used to identify students who were shortlisted after assessment via coloured progressive matrices.
52 items were retained for third and final draft. Items were selected by dimension-wise after calculating difficulty value and discriminating power for the third draft.

Assessment tools

- Tool on Adaptive Reasoning

Adaptive reasoning refers to the capacity for logical thought, reflection, explanation, and justification (Kilpatrick, Swafford & Findell, 2001). This is achievement test consisting 28 items on capacity for logical thought, reflection, explanation, and justification and ability to make connections between diverse mathematical concepts. Each dimension has its subparts. Capacity for logical thought includes generalization, operational sense, understanding of equivalence and comparison, coding decoding and representation. Reflection includes relations, location and movement, rounding decimals, estimated sums and differences and filling the missing number. Explanation includes visual representation, properties of 2-D geometry, classification, national and international place value system and expansion of numbers. Justification includes draw conclusions, demonstration, and description and analysis. Ability to make connections between diverse mathematical concepts includes vocabulary and mathematics language, usage of symbols and relationship of fraction and decimal.

- Tool on Procedural Fluency

Procedural fluency refers to knowledge of procedures, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently (Kilpatrick, Swafford & Findell, 2001). This is an achievement test consisting 28 items on knowledge of facts and procedures, relationship of addition and subtraction, computation, knowledge of multiples, interpretation of division, relationship of multiplication and division, estimation strategies, expansion of knowledge of basic facts, understanding of factors and multiples, development of thinking, knowledge of even-odd and prime-composite numbers, knowledge of HCF & LCM, basics of unitary method, measurement of time & distance, measurement of money and units, procedure of reading and recording time, time conversion, interpretation of calendar, recognition of shapes, composing, decomposing, solve variety of problems and increasing knowledge.

- Tool on Connections of mathematics with other subjects

Connections make mathematics more meaningful and make learning easier. Recognizing and establishing connections can greatly assist students in their efforts to solve problem, reason, and communicate about mathematics. This is an achievement test consisting 33 items on connection with science, literature and arts, social studies and recognization and application of mathematics outside mathematics. Each dimension has its subparts. Connection with science includes measurement of weight, length, litre, area and perimeter and conversion of units. Connection with literature and arts includes measurement of time, knowledge of geometrical ideas and extending patterns. Connection with social studies includes representation and interpretation of data and connection with sports. Recognize and apply mathematics outside of it includes generation and analysis of patterns and their application in daily routine.

Remedial programme
Metacognitive Strategies

Metacognition refers to thinking about one's own thinking which is examining one's own information processing. As Hyde and Bizar (1989, p.51) stated; many students fail to engage in the "self- planning, self-monitoring, self-regulating, self-questioning, self-reflecting, self-reviewing" that is necessary to critical thinking and learning (Hyde & Bizar, 1989). It is also a learning skill. If you have good learning skill means you know how to monitor, regulate, and control your own thinking.
Intervention of use of metacognitive strategies: It included following techniques and materials.

Techniques and models

(a) Self-Questioning: One of the strategies is teacher presenting to them divergent questions or teacher can encourage the students to generate their own questions. Ganz and Ganz (1990) suggest that in teaching the process of self-questioning, teacher may use cognitive behaviour modification. It is a metacognitive strategy in which the teacher demonstrates a task and guides students through the use of instruction and practice.

(b) KWL strategy: This Metacognitive strategy starts with students' discussion of what they know, and a listing of the information. Then students are encouraged to make prediction about what they want to learn. Researcher used this strategy to teach more familiar topics like money, time and metric system (measurement) to students. In this strategy the Frayer vocabulary model was used to teach the geometrical concepts:

- The Frayer model is a concept map which enables students to make relational connections with vocabulary words, which explains definition, characteristics examples and non examples of a concept in a pictorial form.

(c) PQ4R strategy: PQ4R is an acronym for Preview, Question, Read, and Reflect, Relate and Review. This PQ4R strategy assists students to process a lot of information in a relatively short amount of time. It helps the students to orient cognitively to the task at hand prior to actual reading. The strategy was used to teach factors and multiples, number system, lines and angles, patterns and data interpretation. In this strategy the graphic organizers were used.

- Graphic organizers: Graphic organizers are diagrammatic illustrations designed to assist students in representing patterns, interpreting data, and analyzing information relevant to problem-solving (Lovitt & Hordon, 1994; Ellis & Sabornie, 1990). Following are the types of graphic organizers:

a) Hierarchical Diagramming: These graphic organizers begin with a main topic or idea. All information related to the main idea is connected by branches, much like those found in a tree like factors and multiples contain HCF & LCM, number system consists even-odd and prime-composite numbers (Lovitt & Hordon, 1994; Ellis & Sabornie, 1990)..
b) Sequence charts: These charts are designed to symbolize a sequence of procedures or events in a content area. It includes the following steps (Lovitt & Hordon, 1994; Ellis & Sabornie, 1990):

1. Read (for understanding)
2. Paraphrase (in your own words)
3. Visualize (a picture or drawing)
4. Hypothesize (the plan to solve the problem)
5. Estimate (predict the answer)
6. Check (make sure all steps were completed correctly)

c) Compare and contrast: These charts are designed to compare information across two or three groups or ideas (Lovitt & Harton, 1994; Ellis & Sabornie, 1990).

(d) IDEAL strategy: Another approach to metacognition is to Identify, Define, Explore, Act and Look. IDEAL is the acronym for these strategies, which are important for effective and efficient thinking and problem solving (Byrnes, 1996). Each of these specific Metacognitive skills can be taught to students by a teacher who is concerned with facilitating effective thinking and problem solving.

(e) SQ4R strategy: The SQ4R (Survey Question Read Relate Recall Review) strategy involves expansion and discussion between teacher and students. These discussions often lead to a better student understanding of the problem. This strategy was developed to help students arrive at their own solutions through rich discussion. With the help of this strategy, the researcher taught addition, subtraction, multiplication and division. She used mnemonic devices in this strategy.

- Mnemonic devices: Mnemonic devices are memory aids in which specific words are used to remember a concept or a list. The verbal information promotes recall of unfamiliar information and content (Nagel, Schumaker &

Deshler, 1986), e.g. “BODMAS” is commonly used to help students remember the order of operations in mathematics.

(f) Paraphrasing Strategy: The Paraphrasing Strategy is designed to help students restate the math problem in their own words, therefore strengthening their comprehension of the problem (Montague, 2005). With the help of this strategy, researcher taught unitary method, area and perimeter and number stories of basic operations to fourth graders.

Procedure of data collection

On the basis of above tests all the identified cases were assigned to two groups, one experimental group and one control group. Self-made tests called Tool on Adaptive Reasoning; on Procedural Fluency and on Connections of mathematics with other subjects were used to assess adaptive reasoning, procedural Fluency and Connections of mathematics with other subjects. These three measures served as pre test and are dependent variables.
In the next phase, interventions were provided to subjects in treatment group through metacognitive strategies in the form of remediation. 45 sessions each of 40 minutes duration were conducted in groups.
Last phase consisted of re-administration of tests to assess Adaptive reasoning, Procedural fluency & Connections of mathematics with other subjects in order to see the effectiveness of metacognitive strategies. This provided scores of post test.

Treatment

The treatment was given to experimental group by metacognitive strategies and traditional teaching to control group respectively for 45 sessions of 40 minutes each. Control group received treatment for same duration and on same content matter.

## Results

Effectiveness of metacognition strategies on Adaptive Reasoning
The t-values for adaptive reasoning of metacognition strategy group at both pre test and post test level have been presented below in Table 1.

Table 1. t-test for correlated means for adaptive reasoning

| Adaptive Reasoning | N | Mean | Std. Deviation | Std. Error Mean | t-value | r value | p-value |
|---|---|---|---|---|---|---|---|
| Pre-test | 13 | 8.39 | 2.87 | 0.79 | 28.42 | 0.71 | .0001** |
| Post-test | 13 | 25.15 | 1.28 | 0.36 | | | |

Table values of t at 0.05 = 1.711; 0.01 = 2.492; for df = 24
As shown in table 1, the scores of Experimental Group i.e. metacognitive strategies group are represented for adaptive reasoning variable at both pre test and post test level. The difference between pre test and post test means of adaptive reasoning is 16.77 for metacognition strategies group. This difference was found to be significant ($t_{24} = 28.42$ at 0.01). This indicates that subjects performed better after administration of metacognition strategy in adaptive reasoning ability at post test level.

The t-values for adaptive reasoning of metacognition strategy group and control group at post test level have been presented below in Table 2.

Table 2. t-test for independent means for adaptive reasoning in metacognition strategies group and control group

| Groups | N | Mean | Difference in mean | SD | Value of t-ratio | p-value |
|---|---|---|---|---|---|---|
| Metacognition strategies | 13 | 25.15 | 13.09 | 1.28 | 18.92 | 0.0001** |
| Control group | 15 | 12.07 | | 2.19 | | |

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

As shown in the table 2 the subjects in experimental group had higher mean scores in the variable of mathematical skill of adaptive reasoning at post test level than control group which received traditional chalk and talk in adaptive reasoning. There was a difference of 13.09 in the mean scores of experimental group and control group C with Experimental group scoring higher than C. This difference was found to be significant ($t_{26} = 18.92$; $p < 0.01$). This indicates that experimental group had better adaptive reasoning ability at post test level.
Above finding related to experimental group i.e. metacognitive strategies have been supported by other studies (Safari & Meskini, 2016; Lai, Zhu, Chen and Li, 2015; Harandi, Sharbabaki, Deh and Darehkordi, 2013; Alikamar, 2014; Abbasi, Alamolhodaei and Radmehr, 2013; Babakhani, 2011; Bayat and Tarmizi, 2010; Kyong-Eun, 2009; Özsoya and Ataman, 2009; Kvvang, 2000) indicate that reasoning skills in mathematics has improved significantly by metacognition strategies. Various strategies were

suggested by the researchers. Metacognitive strategies showed significant improvement in increasing achievement, motivation, metacognitive skills, attitude and permanence of mathematics among children with dyscalculia. So in the present study, researcher used metacognitive strategies for dyscalculic children for enhancing their reasoning. The results also show that metacognitive strategies e.g. Self-Questioning, KWL strategy, PQ4R strategy, IDEAL strategy, SQ4R strategy, Paraphrasing Strategy develop adaptive reasoning of the subjects. Based on above findings, therefore hypothesis (1) that the children with dyscalculia will improve significantly in adaptive reasoning after administration of metacognitive strategies of intervention is accepted. The children with dyscalculia will improve significantly in adaptive reasoning after administration of metacognitive strategies. Also, the objective of studying the effect of metacognitive strategies on adaptive reasoning of fourth graders with dyscalculia has been fulfilled.

Procedural fluency

The t-values for procedural fluency of metacognition strategy group at both pre-test and post-test level have been presented below in Table 3.

Table 3 t-test for correlated means for procedural fluency

| Procedural Fluency | N | Mean | SD | Std. Error Mean | t-value | r value | p-value |
|---|---|---|---|---|---|---|---|
| Pre-test | 13 | 8.31 | 2.14 | 0.59 | 16.27 | 0.41 | .0001** |
| Post-test | 13 | 23.77 | 3.70 | 1.03 | | | |

Table values of t at 0.05 = 1.711; 0.01 = 2.492; for df = 24

As shown in table 3, the scores of Experimental Group i.e. metacognitive strategies group are represented for procedural fluency variable at both pre test and post test level. The difference between pre-test and post-test means of procedural fluency is 15.4615 for Experimental Group i.e. metacognition strategies group. This difference was found to be significant ($t_{24}$ = 16.27 at 0.01 level). This indicates that subjects performed better after administration of metacognition strategy in procedural fluency ability at post test level.

The t-values for procedural fluency of metacognition strategy group and control group at post test level have been presented below in Table 4.

Table 4. t-test for independent means for procedural fluency in metacognition strategies group and control group

| Groups | N | Mean | Difference in mean | SD | Value of t-ratio | p-value |
|---|---|---|---|---|---|---|
| Metacognition strategies | 13 | 23.77 | 12.10 | 3.70 | 10.84 | 0.0001** |
| Control group | 15 | 11.67 | | 2.09 | | |

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

As shown in the table 4 the subjects in experimental group had higher mean scores in the variable of mathematical skill of procedural fluency at post test level than control group which received by traditional chalk and talk procedural fluency. There was a difference of 12.10 in the mean scores of experimental group (Metacognition Strategies) and control group C with Experimental Group scoring higher than C. This difference was found to be significant ($t_{26}$ = 10.84; $p < 0.01$). This indicates that experimental group had better procedural fluency ability at post test level.

Above finding related to experimental group i.e. metacognitive strategies have been supported by Jbeili (2012) who examined the effect of cooperative learning with metacognitive scaffolding on mathematics conceptual understanding and procedural fluency in learning and solving problems and tasks involving the addition and subtraction of fractions. The results showed that students in group CLMS significantly outperformed students in groups CL and T in mathematics conceptual understanding and procedural fluency. The results also showed that students in group CL significantly outperformed their counterparts in group T in mathematics conceptual understanding and procedural fluency.

The results also show that metacognitive strategies develop procedural fluency of the subjects. Based on above findings, therefore hypothesis (2) that the children with dyscalculia will improve significantly in procedural fluency after administration of metacognitive strategies of intervention is accepted. The children with dyscalculia will improve significantly in procedural fluency after administration of metacognitive strategies. Also the objective of studying the effect of metacognitive strategies on procedural fluency of fourth graders with dyscalculia has been fulfilled.

Connections of mathematics with other subjects

The t-values for connections of mathematics with other subjects of metacognition strategy group at both pre test and post test level have been presented below in Table 5.

Table 5. t-test for correlated means for connections of mathematics with other subjects

| Connections of mathematics with other subjects | N | Mean | Std. Deviation | Std. Error Mean | t-value | r value | p-value |
|---|---|---|---|---|---|---|---|
| Pre-test | 13 | 10.77 | 4.49 | 1.25 | 15.38 | 0.20 | .0001** |
| Post-test | 13 | 30 | 1.91 | 0.53 | | | |

Table values of t at 0.05 = 1.711; 0.01 = 2.492; for df = 24

As shown in table 5, the scores of Experimental Group i.e. metacognitive strategies group are represented for connections of mathematics with other subjects' variable at both pre-test and post-test level. The difference between pre test and post test means of connection of mathematics with other subjects is 19.23 for Experimental Group i.e. metacognition strategies group. This difference was found to be significant ($t_{24}$ = 15.38 at 0.01 level). This indicates that subjects performed better after administration of metacognition strategy in connections of mathematics with other subjects at post-test level.

Table 6. t-test for independent means for connections of mathematics with other subjects in metacognition strategies group and control group

| Groups | N | Mean | Difference in mean | SD | Value of t-ratio | p-value |
|---|---|---|---|---|---|---|
| Metacognition strategies | 13 | 30 | 17.53 | 1.91 | 27.85 | 0.0001** |
| Control group | 15 | 12.47 | | 1.41 | | |

Table values of t at 0.05 = 2.056; 0.01 = 2.779; for df = 26

The t-values for connections of mathematics with other subjects of metacognition strategy group and control group at post test level have been presented below in Table 6.
As shown in the table 6 the subjects in experimental group Experimental Group had higher mean scores in the variable of mathematical skill of connections of mathematics with other subjects at post test level than control group which received traditional chalk and talk in connections of mathematics with other subjects. There was a difference of 17.53 in the mean scores of experimental group and control group C with Experimental Group scoring higher than C. This difference was found to be significant ($t_{26}$ = 27.85; $p < 0.01$). This indicates that experimental group had better understanding of connections of mathematics with other subjects at post test level.
Above finding related to experimental group i.e. metacognitive strategies have been supported by Şahin and Kendir (2013) who studied the effect of using metacognitive strategies for solving geometry problems on students' achievement, metacognitive skills and attitude. The data were analyzed via dependent and independent t-tests, and it was seen that the experimental group had significantly higher posttest scores when compared to the control group. More significant results revealed when quantitative analysis accompanied by student essays. Furthermore, these students had developed the ability to perceive the importance of problem solving, to understand problems, to be involved in planned studying and be aware of the problem solving process. The improvement in their attitude toward geometry and mathematics led to a corresponding increase in their achievement.
The results also show that metacognitive strategies develop connections of mathematics with other subjects of the subjects. Based on above findings, therefore hypothesis (3) that the children with dyscalculia will improve significantly in connections of mathematics with other subjects after administration of metacognitive strategies of intervention is accepted. The children with dyscalculia will improve significantly in connections of mathematics with other subjects after administration of metacognitive strategies. Also the objective of studying the effect of metacognitive strategies on connections of mathematics with other subjects of fourth graders with dyscalculia has been fulfilled.
Metacognitive strategies have been useful in developing adaptive reasoning, procedural fluency and connections of mathematics with other subjects as mathematics skills. Many other studies (Laswadi, Kusumah, Darwis and Afgani, 2016; Hassan and Ahmed, 2015; Ingole and Pandya, 2015; Tok , 2013; Moga (Maier), 2012; Sırmacı and Tuncer, 2012; Toit and Kotze, 2009; Hoe, Cheong and Yee, 2001) also point to similar findings.

## Discussion

Students with dyscalculia struggle with a rapid pacing of introducing new mathematics concepts, and insufficient examples, explanations, practice, and review in general education classrooms. In fact, teachers are willing to provide additional instructional and adapted materials to facilitate the successful learning of students with dyscalculia in their classrooms. The present study is based on the assumption that problems of dyscalculic children can be remediated by suitable measures and various effective intervention strategies. As the quality and availability of technology has dramatically increased in the past decade, researchers and educators have made efforts to apply technology to the mathematics curriculum for students with dyscalculia to enhance their mathematics performance.

In the present study, metacognitive strategies have been found to be useful in developing adaptive reasoning, procedural fluency and connections of mathematics with other subjects among children with dyscalculia as evidenced by a) gain scores in pre to post test stage b) difference in experimental and control group at post test.

The findings also provide a platform for the dyscalculic children to adopt latest technology and develop thinking styles. Overall, intervention strategies are beneficial for the learners in the classroom. But the effects were better in metacognition strategies group than control group.

By using metacognitive intervention strategy, the performance of students in procedural fluency and connections of mathematics with others subjects' has improved more than the students of control group.

Metacognitive strategies have been found to be a useful intervention strategy in which children of experimental group (Metacognition Strategies) gave impressive performance in solving problems related to knowledge of facts and procedures, relationship of addition and subtraction, computation, knowledge of multiples, interpretation of division, relationship of multiplication and division, estimation strategies, expansion of knowledge of basic facts, understanding of factors and multiples, development of thinking, knowledge of even-odd and prime-composite numbers, knowledge of HCF & LCM, basics of unitary method, measurement of time & distance, measurement of money and units, procedure of reading and recording time, time conversion, interpretation of calendar, recognition of shapes, composing, decomposing, solve variety of problems and increasing knowledge. The significant differences in pre test and post test scores makes it evident that metacognitive strategies intervention was successful in achieving mastery over adaptive reasoning, procedural fluency and connections of mathematics with other subjects. Teachers can use metacognitive strategies for children to keep awareness of one's own understanding of knowledge. They can positively enhance the performance of students who have learning disabilities by helping them to develop an appropriate plan for learning information with the help of metacognitive strategies.

On the other side metacognition refers to strategies used to facilitate students understand the way they learn; in other words the metacognitive processes are designed for students to think about their thinking. In this intervention, students gain awareness of the way of their learning; consequently they will definitely make use of these processes to acquire new information efficiently and become more of an independent thinker.

Based on the results obtained in the present study, it is shown that the t-ratio in all the three mathematical skills that shows it doesn't benefit all the mathematical skills equally well. This could be due to complexity of mathematical skills. Adaptive reasoning refers to the capacity to think logically about the relationships among concepts and situations and to justify and ultimately prove the correctness of a mathematical procedure or assertion. Adaptive reasoning also includes reasoning based on pattern, analogy or metaphor (Wikipedia, 2013). Secondly Kilpatrick, Swafford and Findell (2001) and Watson and Sullivan (2008) defined procedural fluency as including skill in carrying out procedures flexibly, accurately, efficiently, and appropriately, and, in addition to these procedures, having factual knowledge and concepts that come to mind readily. Third mathematical skill i.e. connections in mathematics can be found within a mathematical topic, across strands and process standards, and outside mathematics, such as connections to other subjects or real-world contexts. Connections make mathematics more meaningful and make learning easier. Recognizing and establishing connections can greatly assist students in their efforts to problem-solve, reason, and communicate about mathematics (Annenberg Learner, 2015). Thus every experimental treatment affects mathematical skills differently due to their specific characteristics.

With large number of students identified with dyscalculia in schools across India, it is only appropriate to determine if teachers are adequately prepared to make learning and performance effective and efficient for this special population of students. Teachers need to have adequate knowledge of the cognitive, social and behavioral characteristics of students with dyscalculia, so that they are able to design instructional models that work for these students. Knowledge of dyscalculia among teachers is also needed for another reason, in order for professionals to avoid stereotypical description of individuals with dyscalculia, because the success of inclusive classrooms is related to teachers' knowledge of the unique needs of their students.

In conclusion, the metacognitive strategies intervention was more effective in improvement of procedural fluency as compared to control group. However, the generalization is cautioned since the study was conducted on a small sample and also a longer treatment may have proved differently.

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