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INTERACTIVE EFFECT OF META-COGNITIVE STRATEGIES-BASED INSTRUCTION IN MATHEMATICS ON META-COGNITIVE AWARENESS OF STUDENTS

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Abstract

This paper attempts to ascertain the interactive effect of meta-cognitive strategies-based instruction in mathematics on student–outcomes. For this purpose, an intervention programme based on meta-cognitive strategies was developed for students of standard eighth. The intervention programme lasted for about 35 hours spread over eight weeks. The aim of the research was to ascertain whether meta-cognitive strategies instruction facilitates meta-cognitive awareness in students. Paper-pencil tests were used in study. The participants of the study included 135 students. The study consisted of one experimental group consisting of 69 students and one control group consisting of 66 students. The experimental group received the intervention programme and the control group received the traditional, lecture-based, teacher-centred instruction. The data was analysed using the statistical technique of ANCOVA. Meta-cognitive awareness in form of knowledge about cognition and regulation about cognition of students in mathematics is found to be significantly influenced by the intervention programme. The effect size of the intervention programme is high in case of knowledge about cognition and is moderate in case of regulation about cognition of students.

Keywords: Meta-cognitive Awareness and Meta-Cognitive Strategies

1. Introduction and Concept of Meta-cognition

India is a country which predominantly relies on the traditional lecture method of teaching all the subjects including mathematics, in which the Herbartian steps are adopted. Though there is a change in this practice, in case of mathematics instruction it is rather slow. In recent years, many attempts have been made to improve mathematics teaching and learning. One such attempt is made in the present research. There are many innovative techniques that can be used by a teacher to make teaching and learning process more effective. For example, meta-cognitive strategies, in which learners will keep planning and monitoring their own knowledge in mind during the learning activity and assess their performance against them. During the learning activity, teachers can encourage learners to share their progress, their cognitive procedures and their views of their conduct.

1.1 Meta-cognition

Meta-cognition Knowledge and Regulation

Knowledge of meta-cognition can be divided into three groups: declarative knowledge (knowledge about self and strategies), procedural knowledge (knowledge about how to use strategies) and conditional knowledge (knowledge about when and why to use strategies). Regulation of meta-cognition covers five areas: planning (goal setting), information management (organizing), monitoring (assessment of one's learning and strategy), debugging (strategies used to correct errors) and evaluation (analysis of performance and strategy effectiveness after a learning episode). (Baker, 1989; Artzt & Armour-Thomas, 1992)

1.2 Meta-Cognitive Strategies

There are various meta-cognitive strategies aimed at developing learners' meta-cognition. Anderson (1976, 1983, 1993) underlines that "knowledge starts with declarative actions, the conscious and control; and this control paves the way for procedural processes. Moreover, he argues that declarative knowledge forms the basis of knowledge transfers". Procedural knowledge, on the other hand, has significant roles in structuring concepts and obtaining declarative knowledge (Lawson et al., 2000). Blakey and Spence (1990) state that learners should ask themselves what they know and what they do not know at the beginning of a learning activity. Procedural and declarative knowledge forms can be developed through different methods and techniques; or they contribute to the development of different methods and techniques (Howe et al., 2000), Lucangeli, Coi and Bosco (1997) found that fifth graders viewed problems containing large numbers as more difficult than problems with smaller numbers in their study examining the meta-cognition of mathematics difficulty in elementary school children. In this study, students who were classified as poor problem solvers showed lower meta-cognitive awareness and made more errors when solving problem. Such learners keep planning in their minds during the learning activity and assess their performance against them. During the learning activity, teachers can encourage learners to share their progress, their cognitive procedures and their views of their conduct. Learners can become more aware of their own behaviour and teachers are able to identify problem areas in the learners' thinking (Costa, 1984). Accordingly, learners keep the criteria in mind when classifying their opinions about the learning activity and they motivate the reasons for those opinions (Costa, 1984). Guided self-evaluation can be introduced by checklists focusing on thinking processes and self-evaluation will increasingly be applied more independently (Blakey & Spence, 1990).

2. Review of Related Literature on Meta-Cognitive Awareness

Tara et al. (2006) conducted a study of the role of cognition, motivation and emotion in explaining the mathematics achievement gap between Hispanic and white Students. Bertram and Dickhauser (2008) worked on high-school students' need for cognition, self-control capacity and school achievement by testing a mediation hypothesis. Guy and Lee (2005) conducted a study of cognition, meta-cognition and achievement of college students with learning disabilities. Johnson et al. (2010) focused on individual and team annotation effects on students' reading comprehension, critical thinking and meta-cognitive skills. Mevarech and Amrany (2008) conducted a study of immediate and delayed effects of meta-cognition instruction of regulation of cognition and mathematics achievement. Mevarech and Fridkin (2006) worked on the effects of IMPROVE on mathematical knowledge, mathematical reasoning and meta-cognition. Jayapraba (2013) conducted a study of the effects of inquiry-based learning and co-operative learning on meta-cognitive awareness in science class. Jadav (2012) conducted a study which describes meta-cognition has application. Titus and Annaraja (2011) conducted a study to explore the effectiveness of meta-cognitive skills in developing the teaching competency among secondary teacher education students. Maghsudi and Talebi (2009) conducted a study of major issue in discussions about cognitive versus meta- cognitive strategies. Wei's (2008) study was based on the theories of meta-cognition and learner autonomy. Hoffman, and Spatariu (2008) conducted a study of regression design which was used to test the unique and interactive effects of self-efficacy beliefs and meta-cognitive prompting on solving mental multiplication problems. Schmidt and Ford (2003) conducted a study of the interactive effect of goal orientation and meta-cognitive instruction on learning outcomes. Tobias and Everson (2002) conducted a research of knowledge monitoring and its relationship to learning from instruction.

3.Need of the Study

Prior research, especially on Indian students from lower socio-economic background and with an average ability has not been conducted with a view to enhance such students' knowledge about cognition and knowledge about regulation.

Meta-cognitive awareness forms a cognitive doctrine and meta-cognition could begin when cognition fails. It is essential to study the interactive influence of meta-cognitive strategies-based instruction on meta-cognitive awareness of students in mathematics. Meta-cognition enables students to benefit from instruction (Carr et al., 1989; Van Zile-Tamsen, 1996) and influences the use and maintenance of cognitive strategies. While there are several approaches to meta-cognitive instruction, the most effective one involve providing the learner with both knowledges of cognitive processes and strategies (to be used as meta-cognitive knowledge), and experience or practice in using both cognitive and meta-cognitive strategies and evaluating the outcomes of their efforts (develops meta-cognitive regulation).

In the present research, there is an attempt to study the effect of meta-cognitive strategies-based instruction in mathematics on students' levels of Knowledge about Cognition (procedural knowledge, declarative knowledge and conditional) andKnowledge about Regulation (planning, comprehensive monitoring, debugging strategies and evaluation).

Operational Definition of the Terms

- **Meta-Cognition:** Meta-cognition refers to learner's awareness of their own knowledge and cognitive processes and their ability to understand control and manipulate their own cognitive processes.
- **Meta-Cognitive Awareness:** Meta-cognitive awareness is the consciousness about one's own awareness and understanding and regulation of the thinking process.
- **Knowledge about Cognition:** Knowledge about Cognition refers to general knowledge about how human beings learn and process information.
- **Knowledge about Regulation:** knowledge about regulation facilitate the control aspect of learning.
- **Meta Cognitive Strategies:** Meta-cognitive strategies refer to methods used to help students understand the way they learn and refers to the processes designed for students to manage, monitor and evaluate their learning and 'think' about their 'thinking'.

3.1 Statement of the Problem

Interactive Effect of Meta-Cognitive Strategies-based Instruction in Mathematics on Meta-Cognitive Awareness of Students.

3.2 Scope and Delimitations of the Study

In the present study, English medium schools from the Greater Mumbai affiliated to the SSC board have been included. It excludes schools with other media of instruction such as Marathi, Hindi, Urdu, Gujarati etc. The present study includes eighth standard from English medium schools situated in Greater Mumbai. Students from other primary and secondary classes have been excluded. It also excludes schools affiliated to ICSE or CBSE boards.
Aim of the Study: The aim of the study was to ascertain the interactive effect of the intervention programme on meta-cognitive awareness of student.

4. Research Questions

1. Do experimental and control group students' pre-test scores on meta-cognitive awareness in the subject of Mathematics differ significantly?
2. Do experimental and control group students' post-test scores on meta-cognitive awareness (in terms of knowledge about cognition and knowledge about regulation) in the subject of Mathematics differ significantly?
3. What is the effect size of the intervention programme on the meta-cognitive awareness (in terms of knowledge about cognition and knowledge about regulation) in the subject of Mathematics?

5. Methodology of the Study

The present study is aimed at enhancing meta-cognitive awareness of secondary students through the use of meta-cognitive strategies-based instruction. The researcher attempts to provide answers to the question, "Is there an interactive effect of meta-cognitive strategies of students on meta-cognitive awareness of secondary school students?" The researcher has manipulated the method of teaching to ascertain its effect on meta-cognitive awareness of students in mathematics. Hence, the methodology selected is the experimental one. In the present investigation, the following quasi-experimental design has been used: The pre-test-post-test non-equivalent groups design:

$O_1X\ O_2O_3CO_4$
Where,
O_1 and O_3: Pre-test Scores & O_2 and O_4 : Post- test Scores
X : Experimental Group, C : Control Group.

6.Teaching Method

Instructional Material: In the present research, the researcher developed an instructional plan based on meta-cognitive strategies and conventional lecture method. In the present research, instructional plan on topics of cube and cube roots, index, construction of quadrilateral, discount and commission and joint bar graph was developed. The techniques used for meta-cognitive strategies-based instruction in the present investigation included Think-aloud, KWL charts and self-reflection sheets.

The researcher obtained permission from two selected schools for administering the tests and the intervention programme. The researcher first administered the meta-cognitive awareness inventory to both, the experimental and control groups. After the pre-test, the experimental group was taught using the meta-cognitive strategies-based intervention programme and the control group was taught using traditional lecture method. At the end of this, a post-test was administered on the students and scores were analysed using statistical techniques. The researcher has used this design as it was the most feasible one and the interpretation of the results has been cautiously done.

The students of standard VIII of both the schools were taught selected topics in mathematics subject. The content matter covered in both the schools was the same. The intervention programme was given on the basis of content from the text books prescribed by Maharashtra state text book production and curriculum research, Pune, India. In the experimental group, the researcher taught the content matter using the meta-cognitive strategies-based intervention programme. Thirty-five periods from the school time-table were taken up to teach the content in each school. It was spread over thirty-two working days. 5 days per week were taken up for eight weeks, teaching one to two school periods a day of a thirty minute duration each. In the control group, the researcher taught using the traditional lecture method. The content was taught in both the schools in the mornings.

7.Participants

In the present research, the participants consisted of 133 students – both boys and girls from standard VIII of English medium schools situated in Greater Mumbai. The experimental group had 69 students and the control group had 66 students. The schools selected for the study were affiliated to the SSC Board, Mumbai with English as the medium of instruction. The schools were selected randomly using the lottery method. However, the experiment was conducted on intact classes due to reasons beyond the researcher's control. The socio-economic background of these students is low. Besides, the participants have an average IQ. It had 36 girls and 33 boys in the control group and 35 girls and 31 boys in the experimental group.

8. Instruments

Meta-cognitive Awareness Inventory (Schraw& Dennison, 1994): This tool consists of 52 items measuring meta-cognitive awareness. Items were classified into eight sub-components subsumed under two broader categories, namely, knowledge about cognition and regulation about cognition. It is supported by a two-factor model. Its internal consistency reliability was established in the Indian context and was found to be$\alpha = 0.90$. The average inter-correlations between the eight subcomponents were 0.56. The eight sub-components are given as follows:

A. Knowledge about Cognition: i) Declarative Knowledge (8 items), ii) Procedural Knowledge (8 items) and iii) Conditional Knowledge (5 items).

B. Knowledge about Regulation: i) Planning (7 items), ii) Information Management Strategies (10 items), iii) Monitoring (7 items), iv) Debugging Strategies (6 items) and v) Evaluation (6 Items).
In all, there are 17 item for measuring Knowledge about Cognition and 35 items for measuring Knowledge about Regulation.

9.Techniques of Data Analysis

The present research used statistical techniques such as the t-test, ANCOVA and wolf's formula. To compare the pre-test and post-test scores on meta-cognitive awareness, the t-test was used. To compare the post-test score on meta-cognitive awareness of students after partialling out the effect of pre-test scores, the technique of ANCOVA was used. Wolf's formula was used to measure the extent of effectiveness of the meta-cognitive strategies on the dependent variable, namely, meta-cognitive awareness (in terms of knowledge about cognition and knowledge about regulation) of students in Mathematics. One-way ANCOVA was used to study the interactive effect of meta-cognitive strategies on the dependent variable, namely, meta-cognitive awareness of students.

9.1 Data Analyses

Null Hypothesis 1: There is no significant difference in the pre-test scores of students from the experimental and control group on the meta-cognitive awareness (in terms of knowledge about cognition and knowledge about regulation).

TABLE 1: comparison of pre–test of MCA of EG and CG

No	Variable	Group	N	Mean	t	P (Two- tailed)
1.	Knowledge about Cognition	CG	66	10.25	2.79	0.006058
		EG	69	11.41		
2.	Knowledge about Regulation	CG	66	21.79	1.46	0.146684
		EG	69	23.09		

Table 1 shows that the Mean Knowledge about Cognition of students from the experimental group is significantly greater to that of the control group. On the other hand, the Mean Knowledge about Regulation of students from the experimental group is significantly less than that of the control group. Thus, the null hypothesis is accepted for Knowledge about Regulation, but rejected for Knowledge about Cognition.

Due to the rejection of the null hypothesis for Knowledge about Cognition, as well as due to the fact that the final selection of the participants was done as intact class, the technique of ANCOVA was used to compare the post-test scores of Knowledge about Cognition and Knowledge about Regulation of students in which their respective pre-test scores have been partialled out.

Null Hypothesis 2: There is no significant difference in the post- test scores of students of experimental group and control group of meta-cognitive awareness (in terms of knowledge about cognition -KC) after controlling for the pre-test scores.

One-way ANCOVA was used to test this hypothesis as shown in table 2.

Table 2: Comparison of post –test KC of EG and CG

Variable	Groups	Observed Mean	Adjusted Mean

Knowledge about Cognition	Experimental	12.0448	12.0449
	Control	10.7879	10.7877

It was found that the $F_{y.x} = 27.18$ ($p<0.000001$). Hence, a significant difference is found between the two groups. Thus, the null hypothesis is rejected. It can be stated that there is a significant difference in the post-test scores of students' meta-cognitive awareness (in terms of knowledge about cognition) of the experimental and control groups. The Mean KC of students of the experimental group is significantly greater than that of the control group. Thus, it may be concluded that the meta-cognitive strategies-based intervention programme has been effective in enhancing knowledge about cognition in mathematics amongst students of standard eighth.

Null Hypothesis 3: There is no significant difference in the post- test scores of students of experimental group and control group of meta-cognitive awareness (in terms of knowledge about regulation-KR) after controlling for the pre-test scores

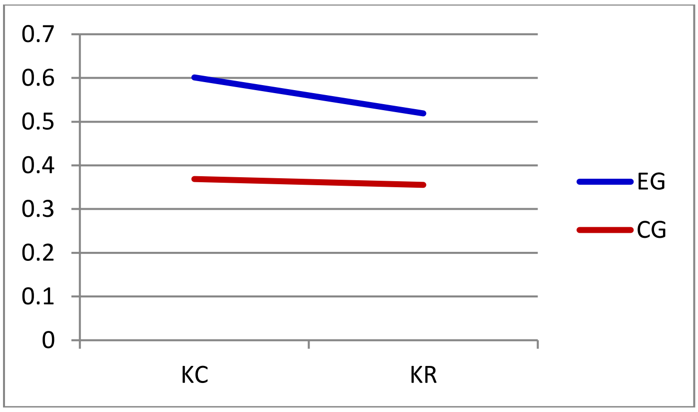
One-way ANCOVA was used to test this hypothesis as shown in table 3.

Table 3: Comparison of post –test KR of EG and CG

Variable	Groups	Observed Mean	Adjusted Mean
Knowledge about Regulation	Experimental	24.02	24.49
	Control	21.53	21.05

It was found that the $F_{y.x} = 16.81$ ($p<0.000072$). Hence, a significant difference is found between the two groups. Thus, the null hypothesis is rejected. It can be stated that there is a significant difference in the post-test scores of students' meta-cognitive awareness (in terms of knowledge about regulation) of the experimental and control groups. The Mean RC of students of the experimental group is significantly greater than that of the control group. Thus, it may be concluded that the meta-cognitive strategies-based intervention programme has been effective in enhancing knowledge about regulation in mathematics amongst students of standard eighth.

The following graph shows mean score of KC and KR of the EG and CG (average value on each item).



The graph shows that the difference in Knowledge about Cognition of students from the experimental group is the more than that of Knowledge about Regulation.

Computation of the Magnitude of the Effect SizeUsing Wolf's Formula

Table 4 shows the magnitude of the effects of the meta-cognitive strategies-based intervention programme on students' knowledge about cognition and knowledge about regulation.

Table 4: Effect size

Dependent Variable	**Effect Size**
Knowledge about Cognition	1.25
Knowledge about Regulation	0.77

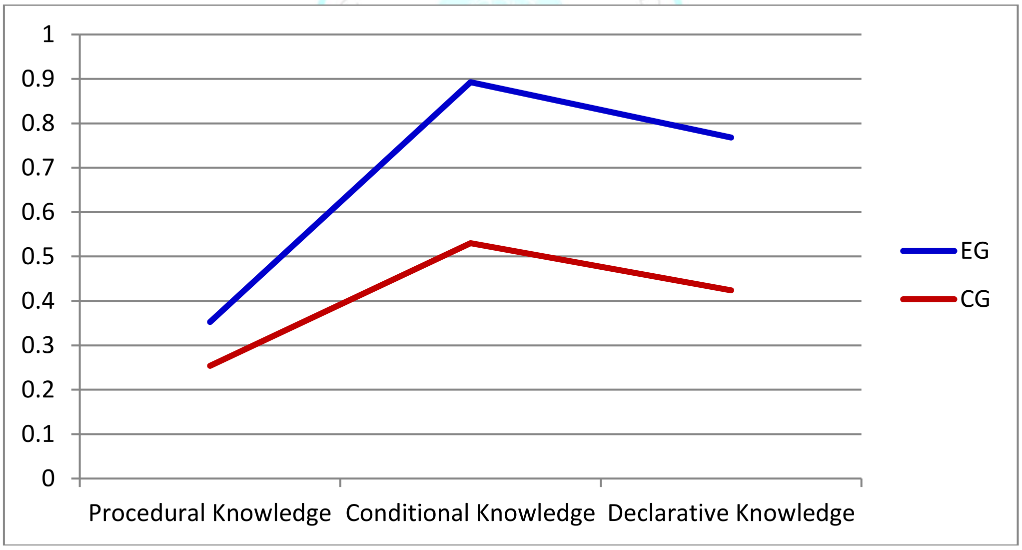
It can be seen that the effect of the intervention programme on knowledge about cognition is high and knowledge about regulation of students is moderate.

Conclusions

It may be concluded that:

- The mean post-test scores of knowledge about cognition and knowledge about regulation of students from the experimental group are found to be significantly greater than that of the control group after partialling out the effect of the respective pre-test scores.
- The meta-cognitive strategies-based instruction has been found to be effective in enhancing knowledge about cognition and regulation about cognition of students. The effect of the meta-cognitive strategies programme on knowledge about cognition is high whereas it is moderate on knowledge about regulation of students.

Further graphical analysis of the components of Mean score on each item on Knowledge of Cognition, namely, Procedural Knowledge, Conditional Knowledge and Declarative Knowledge of students from the experimental and control groups is as follows:



The graph shows that the difference in Conditional Knowledge of students from the experimental group is the maximum followed by Declarative Knowledge and Procedural Knowledge in that order.

Further graphical analysis of the components of Mean score on each item on Knowledge of Regulation, namely, Planning, Information Management Strategies, Comprehension Monitoring, Debugging Strategies and Evaluation of students from the experimental and control groups is as follows:

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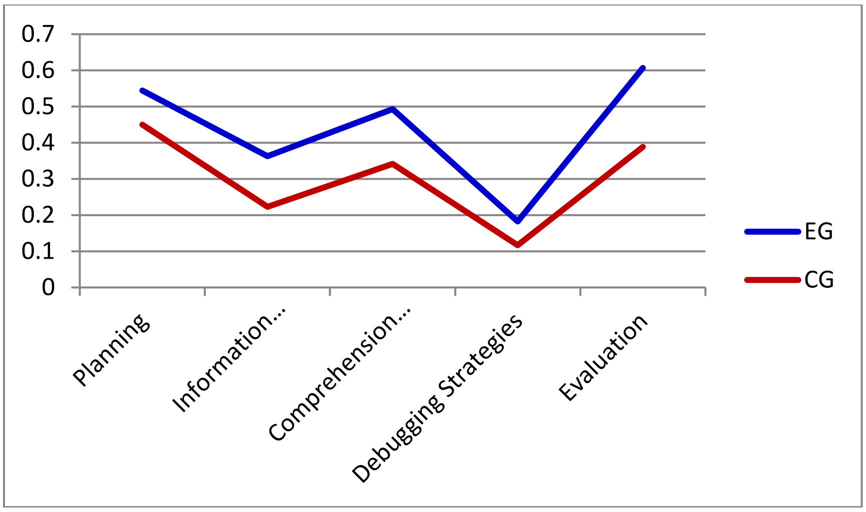

The graph shows that the difference in Information Management Strategies, Comprehension Monitoring and Evaluation of students from the experimental group is the maximum followed by Planning and Debugging Strategies in that order.

Discussion: This present study contributed to an understanding of how meta-cognitive strategies could be used effectively for teaching of Mathematics. Swanson (1990) indicated that metacognitive knowledge and intellectual aptitude were unrelated and that metacognitive skills helped children of lower aptitude compensate on problem-solving tasks. Thus, the findings of the study are very much appropriate in the context of the participants of the present study who are from the lower socio-economic back ground and with average ability.

The experiment has been more successful in enhancing knowledge about cognition which comprised of three distinctive, but interconnected, features of knowledge, namely, declarative, procedural, and conditional knowledge. These three types of metacognitive knowledge are expected to enhance academic development and performance of students who are predominantly accustomed to traditional method of teaching. Traditional teaching in India places emphasis on rote learning and passing the examination. The study, therefore, is of immense importance in the Indian context.

These students are now expected to have a better knowledge of self, task and strategies or actions, how to apply procedures such as learning strategies or actions to make use of declarative knowledge and achieve goals and when and why to apply various procedures, skills and cognitive actions or strategies for improved academic development. Besides, students are now expected to have improved skills of planning, monitoring, and evaluation i.e. meta-cognitive or executive control. It is expected that students, if taught using meta-cognitive strategies-based instruction will have improved skills of selecting appropriate strategies and the resources necessary for reaching goals, goal setting, stimulating prior knowledge and planning time. They would now have better skills of self-testing crucial to adjust or control learning and critically analyses the effectiveness of the strategies or plans being implemented and would employ in intermittent self-testing. They would also evaluate their advancement made toward goals.

On the other hand, students having higher knowledge about regulation are more intrinsically motivated and attempt to comprehend the content-matter rather than merely focus on learning a high grade and that is why students would work hard to learn knowledge about regulation. This may be because of the systematic steps of planning, goal setting and allocating resources prior to learning with information management strategies, skills and strategy sequences used to process information.

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