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THE EFFECT OF METACOGNITION INSTRUCTION ON SOLVING MATHEMATICAL PROBLEMS IN SCIENCE LESSONS

PhDc. Nurhan Yıldız
Gazi University Ankara- Turkey
mumaynur@gmail.com

Prof. Dr. İlbilge Dökme
Gazi University Ankara- Turkey
ilbilgedokme@gmail.com

Abstract
This study examines the metacognitive instruction's effect on solving mathematical problems in science concepts. Metacognitive skills are the strategies on solving mathematical problems, reading, conceptualizing, and writing. In this study, Mayer's four types of processes that translation, integration, planning-monitoring, and solution execution were administered as an instructional practice to 27 6th grade students in a science class. The pre and post test (Speed of Sound Achievement Test) were conducted to control and experimenter groups. The results showed that there was no significant difference between pre-test scores of experimental and control groups, however there was a significant difference between post and pre test scores of experimental group. Additionally, it was seen that students' work were improved and the time spent for each problem was decreased. Some students did not show improvement during the implementation, they were additionally interviewed by the experimenter. They expressed that because of the "Motivational" occasions; they did not show improvement.

Keywords: Cognition, Metacognition, Motivation.

INTRODUCTION

Education and Cognition-Metacognition-Motivation

Generally educational activities are attributed to cognitive processes. According to cognitive/rationalist perception, understanding concepts in different subject domains require cognitive activities; such as reasoning, conceptualizing, solving mathematical problems, planning, and interpreting (Greeno, Collin, Resnick, 1996). However cognitive processes are not always seen as a direct mean of success. For example a student can solve a mathematical problem, after he learns about it. This means he puts the work cognitive abilities, in other words he makes a success of retention test. However when he is asked another mathematical problem which can be solved by integrating information what he already knows, he may not be able to solve it, because he has not seen this topic yet. This means, he can retain but not transfer the knowledge (Mayer, 1996). Such a phenomenon can be attributed to metacognition strategies, one can handle. Beside the cognitive and metacognitive processes, motivational situations are also important variable to solve mathematical concepts. Motivational aspect of the learning is an old and long theoretical framework that there is a huge of studies deep motive. Mayer (1998) categorized the motivational effect on learning by learner's interest, self-efficacy, and attributions. According to Dewey (1913), a learner who has a "will" is probably come up with a permanent learning outcome, rather than an unwilling learner. When learner feels that s/he can do a task, or motivated externally (i.e. by an instructor) s/he probably learns the subject matter (Bandura, 1977). Finally, according to attribution theory, a learner can become more successful or the exact opposite when s/he attributes the success and failure to work or ability.

Metacognition and Mathematical Problem Solving

Problem solving in mathematics is process of the finding ways to discover unknown elements from the given knowledge by using solver's strategies. In order to find the way to process, solver should transfer the knowledge, instead the use of direct elements. Doing so is not only the work of cognitive abilities and motivation, but also sophisticated way of thinking. Solver should know how to organize knowledge and find a way to go ahead. At the beginning metacognitional activities were attributed to only memory and reading, solving mathematical problems was seen as a work interest in cognitional abilities at the point of solving problem. However such a sophisticated thinking can be deepen by metacognitional strategies.

Flavell (1976) defines that "metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data", and "Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective."

Pólya (1973), Fernandez, Hadaway and Wilson (1994), and Mayer (1985) developed specialized methods evoking one's problem solving ability by metacogtional strategies. These three methods are similar in the process, however cited in different phrases.

Mayer's Method for Solving Problem

Mayer's model for solving mathematical problems constitutes translation, integration, planning-monitoring, and solution execution.

Translation refers to express the words operationally in a problem, what certain words mean to solver? Are there any unknown words in the problem? Here is an example from this research's study context.

Question: A child shouts against to a mountain, and hears his sound after 4 seconds. If sound gets on the air with a speed of 344 m/s; what is the distance between child and mountain?

In order to solve this problem only the knowledge of "distance equals to elapsed time multiplied by speed" is not enough. Here, solver should not treat "mountain" word as "elevation of the earth's surface"; he should arrive at a conclusion that in that question mountain means a surface that sound is echoed.

Integration refers to join what the solver knows already, when a solver has a broader schematic knowledge and practice, he can integrate well. In this question solver should know that sound will be echoed from the mountain, since the sound goes to mountain and turns back; elapsed time is actually 2 second (4/2=2). Consequently he should multiply 344 m/s by 2 second, not 4 second.

Planning-Monitoring refers to organize the knowledge and extract the sub-problems in order to make a decision about how to solve it. For example, in this question, there are two knowledge hindered. First, solver should know that from the mountain the sound will be echoed. Second, solver should know that distance equals the elapsed time multiplied by speed of sound.

Solution execution refers to making calculations according to plan. Making true operations is crucial. For example, in this question; "344 m/s x 2 s = 688 m" is the expected answer.

Solving Mathematical Problems in Science Concepts

Sometimes, in science lessons, mathematical relations are used. While a lab section, or test-and-drill exercises a student needs to put mathematical practices on. In Turkey middle school science curriculum, science concepts have been simplified; that is difficult mathematical problems were eliminated; nevertheless, there are main mathematical relations left.

- 5th grade's mathematics ability requiring units: "Kuvvetin Büyüklüğünün Ölçülmesi" (Measurement of Force Magnitude)

- 6th grade's mathematics ability requiring units: "Kuvvet ve Hareket" (Force and Motion), "Maddenin Tanecikli Yapısı" (The Particle Structure of Matter), "Işık ve Ses" (Light and Sound), "Elektriğin İletimi" (Transmission of Electricity)
- 7th grade's mathematics ability requiring units: "Kuvvet ve Enerji" (Force and Energy), "Maddenin Yapısı ve Özellikleri" (Structure of Matter and Properties), "Elektrik Enerjisi" (Electrical Energy)
- 8th grade's mathematics ability requiring units: "Basit Makineler" (Simple Machines), "Maddenin Yapısı ve Özellikleri" (Structure of Matter and Properties), "Işık ve Ses" (Light and Sond), "Maddenin Hâlleri ve Isı" (Phases of Matter and Heat)

Purpose of the Study

The purpose of the present study was to see the effect of the Mayer's metacognition instruction for solving mathematical problems in science lesson. Hence major research questions were these: (1) What is the effect of metacognitive instruction on middle school students' mathematics achievement? and (2) Does students spend less time for each exercises during the implementation (3) What are the opinions of the non-performed students during the implementation.

METHOD

The Sample and Design of Study

This study addresses the needs of middle school students by using metacognitional instruction for solving mathematical problems in science lesson. The sample included 19 female and 27 male 6th grade students. Because of the school structure, all female students were in same class, called Class-B; and all the male students were in same class, called Class-A. The experimenter adopted a quasi-experimental design with two groups pre-test/post-test (Cohen, Manion, and Morrison 2011) to investigate the effectiveness of a repertoire of interventions to enhance middle school students' metacognitive capabilities in solving mathmetical problems in science lesson. Same teacher instructed science lesson to both classes. Teacher was also the experimenter of this study. Since the school population was not much enough; only for one class, the metacognitional instruction was applied. The Class B was chosen to be the control group (N=19); and the Class A (N=27) was chosen to be the experimenter group.

Procedure

The experimenter spent two weeks (8 lesson hours) to implantation of the study to the experimenter group by class activities. The control group used the traditional approach focusing on students' getting the right answers.

Table 1: Time-and-Motion Log

Time (min.)	Activity	Time (min.)	Activity
80	What is Metacognition? (discussion)	10	Regulation and warm up class
40	Pre-test (Speed of Sound Achievement Test)	10	Students' answer to 2nd problem was controlled by teacher.
10	Regulation and warm up class	15	3rd problem (Metacognitive way)
10	Problem Solving question (Non-metacognitive way)	10	Students' answer to 3rd problem was controlled by teacher.
30	1st problem (Metacognitive way)	5	Regulation and warm up class
5	Regulation and warm up class	10	4th problem (Metacognitive way)
15	Students' answer to 1st problem was controlled by teacher	10	Students' answer to 3rd problem was controlled by teacher.
20	2nd problem (Metacognitive way)	40	Post-test (Speed of Sound Achievement Test)

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An example from the experimenter group is following:
Question:……… The car gives 1 hour break……
Student: Here, break <u>means</u>, the driver does not go. So I should reduce 1 hour from the total elapsed time.

Speed of Sound Achievement Test (SSAT)
The implementation was applied to the control and experimenter group (6th graders) when had not learnt the speed of sound concepts yet. However they had learnt how they can calculate the speed in general. Also students knew what the echo of sound is. Experimenter decided to develop 5 open ended question in Turkish (Appendix-A). After forming the questions, a Turkish teacher revised the test in terms of linguistic grammar, and a math and a science teacher revised the test in terms of knowledge accuracy. Thus SSAT was assumed as valid. After then, the answer key was formed by the experimenter. Each question was valued as 20 points; each error of computing reduced the 5 points from the total points (Appendix-A).

For the reliability of a test, the most commonly used statistic is Cronbach's coefficient alpha. While different levels of reliability are required, depending on the nature and purpose of the scale, Nunnally (1978) recommends a minimum level of .7 (Pallant, 2007). So the Cronbach's coefficient alpha was calculated. In the current study, according to pre-test scores the Cronbach alpha coefficient was .71; and according to post-test scores the Cronbach alpha coefficient was .85. Hence the SSAT was assumed as reliable.

RESULTS

The Independent Sample t-test (Comparing Pre-Test scores)
An independent-sample t-test was conducted to compare the pre- SSAT scores for experimental (Class-A) and control (Class-B) groups. The significant figure is larger than .05 There was no significant difference in scores for experimental group (*M* = 35.00, *SD* = 20.28) and control group (*M* = 15.83, *SD* = 18.19; *t* (42) = 1.92, *p* = .06, two-tailed)(Table 2). Cosequently the groups are the same (equal variance assumed).

Table 2: Independent sampe t-test of pre- SSAT scores

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Qsum	Equal variances assumed	,150	,701	-1,923	43	<u>,061</u>	-11,95	6,22	-24,489	,582
	Equal variances not assumed			-1,938	40,03	,060	-11,95	6,17	-24,416	,509

The Paired Sample t-test (Comparing experimental group's pre and post SSAT scores)
A paired-sample t-test was conducted to evaluate the impact of the intervention on students' scores on the SSAT. There was a statistically significant increase in SSAT scores from pre-test (*M* = 35.00, *SD* = 20.28) to post-test (*M* = 56.09, *SD* = 30.26), *t* (23) = 4.05, *p* <.005 (two-tailed). The eta squared statistic (.43) indicated a large effect size.

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Table 3: Paired sample t-test of experimental group's pre-post scores

Sex			Paired Differences					t	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
Boy	Pair 1	Qsum sQsum	--21,09	24,998	5,212	-31,897	-10,277	-4,045	22	,001

Time Elapsed For Exercises

A total of four problems were asked students to solve. For each problems, students were expected to go through four stages of Mayer. Students in general solved the first problem in 30 minutes, then students solved second, third and forth problems in respectively in 20, 15, and 10 minutes. From that, it can be inferred as the elapsed time for solving the problems decreased in the lengt of time.

The Low Performing Students' Attitudes toward Metacognitive Instruction

Students in general were willing to fill all stages of Mayer Metacognition instruction, however some students did not process, either they filled one stage, or they filled none. A qualitative research was designed. Experimenter conducted an interview with three students, the anwers were coded and the frequencies were given following.

1. How do you feel in mathmatics?

Table 4: Frequencies to "How do you feel in mathmatics?" question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	ıt was Hard	2	66,7	66,7	66,7
	little succes	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

According to students' response; 66,7% of students found mathmatics "difficult" and 33,3% of students felt little success in mathmetics.

2. How do you feel seeing a mathmetics question in science lesson?

Table 5: Frequencies to "How do you feel seeing a mathmetics question in science lesson?" question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Normal	2	66,7	66,7	66,7
	Weird	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

According to students' response; 66,7% of students expressed that seeing a mathmatics problem in science lesson "normal" and 33,3% of students expressed that it is "weird".

3. If it Was a Test From Another Dicipline, What Do You Do?

Table 6: Frequencies to "If it Was a Test From Another Dicipline, What Do You Do?" question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	i give empty	**2**	**66,7**	**66,7**	**66,7**
	i did not give empty	1	33,3	33,3	**100,0**
	Total	3	100,0	100,0	

According to students' response; 66,7% of students expressed that they again give no work and 33,3% of students expressed that i do some work.

4. What is the Main Cause that you did not Complete the Work?

Table 7: Frequencies to "What is the Main Cause that you did not Complete the Work?" question

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**i did not understand technic**	2	66,7	66,7	66,7
	boredom	1	33,3	33,3	100,0
	Total	3	100,0	100,0	

According to students' response; 66,7% of students expressed that they i did not understand technic and 33,3% of students expressed that i some just felt bored.

DISCUSSION

As the previious studies revealed the metacognitional strategies carried on the instructional designs, mathematical problems were solved by students in success. Same result was obtained in also this study. The students who were subjected to metacognitional strategies achieved more in SSAT compared to control group. In this study, It was also seen that motivationa sitıations of students were also important for the students achievement in solving mathematical problems.

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Appendix A

İbrahim Uçinyar 6/B 347

0 1. Sesin 340 m/s hızla yayıldığı bir ortamda engele bağıran bir kişi, sesinin yankısını 6 saniye sonra duyar, buna göre engel kişiden kaç m ileridedir?

10 2. Kendisinden 1020 m uzaklıkta bulunan engele doğru şekildeki gibi bağırmakta olan çocuk sesinin yankısını kaç saniye sonra duyar? (Sesin havadaki sürati 340 m/s)

0 3. Su içerisinde balık sürüsüne sonar cihazından gönderilen ses dalgaları 4 saniye sonra geri dönmektedir. Balık sürüsü kaç metre uzaklıktadır? (Sesin sudaki yayılma sürati 1450 m/s)

0 4. Bir tren rayına taşla vuran bir çocuğun çıkarttığı sesi, kulağını tren rayına dayayan başka bir çocuk 2 s sonra duyuyor. Bu iki çocuk arasındaki mesafe kaç m'dir? (Sesin demirdeki yayılma sürati 5130 m/s)

0 5. Sesin yayılma süratinin 1000 m/s olduğu bir ortamda ses kaynağından çıkan ses 8 s sonra kaynağın olduğu yerde duran kişi tarafından işitilmektedir. Buna göre engel ve kişi arasında ne kadar mesafe bulunur?

340 : 6 = 56.6666

1020 : 340 = 3

1450 : 4 = 362,5

5130 : 2 = 2565

1000 : 8 = 125

A random student's work

Toplam puan: 100.

Her işlem hatasından 5 puan azaltılır.

İsim-Soyisim: Sınıf:

10+10 1. Sesin 340 m/s hızla yayıldığı bir ortamda engele bağıran bir kişi, sesinin yankısını 6 saniye sonra duyar, buna göre engel kişiden kaç m ileridedir?

$6:2=3$

$340m/s \times 3 = 1020m$

(ya da $340m/s \times 6 = 2040m$, $2040m : 2 = 1020m$)

10+10 2. Kendisinden 1020 m uzaklıkta bulunan engele doğru şekildeki gibi bağırmakta olan çocuk sesinin yankısını kaç saniye sonra duyar? (Sesin havadaki sürati 340 m/s)

$\frac{1020}{340} = 3$ $\quad 3 \times 2 = 6$ ya da

($1020 \times 2 = 2040$ $\quad 2040 : 340 = 6$)

10+10 3. Su içerisinde balık sürüsüne sonar cihazından gönderilen ses dalgaları 4 saniye sonra geri dönmektedir. Balık sürüsü kaç metre uzaklıktadır? (Sesin sudaki yayılma sürati 1450 m/s)

$4:2=2$ $\quad 1450 \times 2 = 2900m$

ya da

($1450 \times 4 = 5800m$ $\quad 5800:2=2900$)

20 4. Bir tren rayına taşla vuran bir çocuğun çıkarttığı sesi, kulağını tren rayına dayayan başka bir çocuk 2 s sonra duyuyor. Bu iki çocuk arasındaki mesafe kaç m'dir? (Sesin demirdeki yayılma sürati 5130 m/s)

$5130 \times 2 = 10260m$

10+10 5. Sesin yayılma süratinin 1000 m/s olduğu bir ortamda ses kaynağından çıkan ses 8 s sonra kaynağın olduğu yerde duran kişi tarafından işitilmektedir. Buna göre engel ve kişi arasında ne kadar mesafe bulunur?

$1000 \times 8 = 8000$ $\quad \frac{8000}{2} = 4000$

ya da $8:2=4$ $\quad 1000 \times 4 = 4000$

Answer Key