EFFECTIVENESS OF METACOGNITION TRAINING AND SHORT-TERM DAILY PRACTICE OF MATHEMATICS IN ACADEMIC ACHIEVEMENT AND ATTITUDES TOWARDS MATHEMATICS

[a*]SAADI LOTFALI, [b]ZARGHAM GHANBARPOUR ALEM

[a]*Cognitive Psychologist (MA), Institute for Cognitive Sciences Studies-Tehran, Iran & Family Consulting center (Learning disability therapist)& School consultant in education. Second district in karaj city, Iran*
[b] *School consultant (MA), Faculty of Psychology and Educational Sciences, Allameh Tabataba'i University. Tehran, Iran& Family Consulting center (Family therapist) & School consultant in education. Second district in karaj city, Iran*

Email: [a]*Saadi_lotfali@yahoo.com,* [b] *zghanbarpor@yahoo.com*

Abstract. An experimental pretest post-test control group research design was used for the conduct of this study in which 50 junior high school students with weak performance in mathematics were selected by purposive sampling method. These participants were then assigned randomly in experimental and control groups (25 participants in each group). The obtained data were analyzed using descriptive and inferential statistics, which included repeated measures ANOVA. The results of data analysis showed that metacognitive skills training and daily short-term practice of mathematics had a significant effect on the students' attitudes towards mathematics and their performance in this course in the experimental group. It is notable that this significant impact was at play after three months from the passage of the intervention.
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Keywords: metacognition training, academic achievement, attitudes to mathematics

1 Introduction

Mathematics or calculation has been called the universal language. Calculation is a symbolic language that enables human to think about things, record them, and relate thoughts and relations between quantities to each other. In the present age, education and training, and generally education constitute an important part of people's lives; furthermore, the quality and quantity of education also plays an important role in the future of people. Accordingly it is for almost a century that psychologists are widely seeking to identify predictors of academic achievement. In different societies, professional groups and psychologists have always emphasized the review of various aspects of education and the effective factors in it (Lounsbury, Steel, Loveland & Gibson, 2004). In this way, not only students and their families spend huge costs on the education of students at different levels of education, but also the society spends huge costs. Thus, the achievement of positive results in the field of education along with the identification and control of the factors affecting academic achievement can lead to all-round development of students and the community. Teachers and students believe that mathematics is essential in daily life due to its widespread use and competency in mathematics is a crucial predictor of economic efficiency in the society (Ministry of Education, Ontario, 2005). Mathematics is an important lesson in education for the preparation of students for jobs. Math skills are often considered as a filter for professional life pathway. The study of the factors affecting academic achievement in math course has attracted the attention of educators more than ever over the past three decades (Wang, Fuchs & Fuchs, 2016). The sense of inability in mathematical problem solving or a lack of talent in math along with feeling of low level of math intelligence may gradually cause negative attitudes towards math. Attitudes are defined as positive or negative emotional dispositions; and motivational elements have been composed of beliefs, attitudes, values, and concerns (Aiken, 2000). Students' attitudes toward math are among the main components correlated with performance in this course (Pimta, Tayruakham & Nuangchalerm, 2009). Research findings have shown that academic achievement in math depends on information processing procedure, science structure, and motivational factors (Bassant, 1995). It is notable that these factors (attitude toward math, performance, inability in math or lack of talent) support each other as a cycle. The improvement and compensation of students' weaknesses in mathematics can have an important role in students' academic motivation. Mathematics can be ta paly as one of the academic courses determining the future of students due to its important role in the continuity of education (Park et al., 2016).

Metacognition refers to the knowledge that people have about their thought processes; similarly, metacognition has been also defined as thinking about learning. Metacognition has been defined as people's knowledge about how to make efficient use of cognitive processes and achieve learning objectives. Successful students not only act efficiently in the acquisition, storage, and retrieval of knowledge when needed (cognitive processes), but they also supervise their own perception of the contents and the accomplishment method of these processes. They will do an appropriate action whenever they find themselves confused. In addition, such students are autonomous individuals because they themselves monitor their own understanding and learning by means of their metacognitive knowledge. Here, the teacher does not monitor their learning by asking questions (Jacobse & Harskamp, 2010). Kai (1992) concluded that progress in mathematics largely requires the awareness of different learning strategies and their implementation. Vaidya (1999) showed that meta-cognitive activities have monitoring nature and can be used as a convenient tool for learning mathematics. Montague (1996) argues that teachers cannot teach mathematics in such a way that it can come long lasting if they are not familiar with metacognitive teaching methods.

Metacognitive knowledge refers to a set of beliefs that people have about themselves, mathematics, and nature of mathematical thinking. For example, many students believe that they should remember the mathematical thoughts and formulas that are transferred by professionals in authority, such as teachers. Therefore, they expect to have ready-made formulas at their disposal for the situations that they have already studied. In this regard, they may easily succumb or cannot cope with the analysis of the situations they have been able to understand if they forget the formulas. This knowledge can be used in a variety of exercises and lesson plans. One of these methods can be taught to individuals in the form of daily exercises. This study was an attempt to embark on teaching these skills in a variety of exercises, such as presentation of problem-solving skills motivational short-term exercises, utilization of learning and imaginative strategies in mathematics performance, and attitudes towards mathematics.

The present study aims to examine whether teaching of metacognition skills and short-term daily exercises can improve academic achievement of weak students in mathematics and promote their positive attitudes towards this course.

2 Method

A quasi-experimental research design along with pretest posttest control group was used foe the conduct of this study. All the junior high school students of Ghasem ibn al-Hasan constituted the statistical population of this study. From among this population, 50 junior high school students with weak performance in mathematics were selected by purposive sampling method. It is noteworthy that these participants were selected with the observance of inclusion and exclusion criteria, such as no consumption of psychiatric drugs, not suffering from any physical illness, and informed consent. These participants were then assigned randomly in experimental and control groups (25 participants in each group). The experimental group received metacognitive skills towards learning mathematics; furthermore, this group was provided with the explanation on the persistent factors contributing to weakness in mathematics. Also the effectiveness of the current intervention program in mathematical achievement and the improvement of attitudes to mathematics were presented. Accordingly, this group was trained by short-term mathematical practices on daily basis. Both groups were evaluated before, during, and after the intervention based on Aiken's Mathematics Attitude Scale and academic achievement score in mathematics. The obtained data were analyzed using descriptive and inferential statistics, which included repeated measures ANOVA.

3 Instrumentation

3.1 Attitude toward Mathematics Scale

Attitude toward Mathematics has been measured with "Attitude toward Mathematics Scale" (Aiken, 1979, Aiken & Groth-Marnat, 2005). This scale consists of 24 items that are scored in a 5-point Likert scale (SD=Strongly Disagree, D=Disagree, U=Undecided, A=Agree, SA=Strongly Agree). This scale consists of four subscales, namely pleasure, important, motivation, and fear toward mathematics. The re-test reliability coefficient of the total scale has been reported to range from 0.90 to 0.94 (Aiken & Groth-Marnat, 2005). The reliability of this sale has been confirmed in several international studies (Yushau, 2006; Wong, 2001; Olson, 2002).

3.2 Intervention

In the present study, three dimensions were taken into consideration. The first one was aimed at the best way for learning mathematics. For this purpose, metacognitive strategies were taught to students in one session to learn and practice how to solve mathematical problems. The second dimension of this intervention consisted of teaching how to do daily exercises and practices (the number of math problems that students must solve per day). This dimension also included the concentration on the short-term effectiveness of daily exercises in terms of cognitive and motivational learning. The third dimension contained the registration of activities as monitoring their own activities and reporting of daily activities. In fact, the students wrote down and reported their daily activities in a table. In addition, students were informed of their progress by self-assessment and teacher assessment. It is noteworthy that such factors as metacognition training metacognitive strategies in learning, bodily training of reading and math homework, teaching of background construction and problem solving, teaching of monitoring, review of the previous sessions, and the fulfillment of homework were the main themes of metacognition training.

3.3 Academic achievement in mathematics

Academic achievement in mathematics has been measured by an academic achievement test prepared by teachers. The results were then analyzed using SPSS Software.

4 Results

In Table 1., the mean scores of experimental and control groups have been shown for each component of attitudes towards mathematics as well as math scores in pre-test, post-test, and follow-up stages.

Table 1: The mean scores of two groups for attitudes towards mathematics and math scores in pre-test, post-test, and follow-up stages

Variable	Group	Mean before treatment	Mean after treatment	Mean of follow-up test
Fear	Experimental	21.81 (5.08)	17.88 (4.29)	18.62 (4.25)
	Control	22.14 (5.18)	21.96 (4.56)	21.77 (4.05)
Important	Experimental	22.88 (5.02)	18.12 (4.06)	18.69 (4.85)
	Control	22.12 (4.39)	21.23 (4.68)	21.46 (3.73)
Motivation	Experimental	15.92 (2.65)	21.00 (3.77)	20.16 (4.78)
	Control	17.73 (3.40)	17.23 (3.44)	16.88 (3.52)
Pleasure	Experimental	18.05 (3.70)	23.78 (3.60)	21.69 (3.16)
	Control	19.58 (4.63)	18.77 (4.86)	18.31 (3.46)
Math Score	Experimental	10.50 (2.47)	16.00 (1.70)	15.65 (2.81)
	Control	10.07 (2.56)	10.46 (2.06)	10.81 (2.38)

Repeated measures ANOVA was used to analyze the collected data. For this purpose, the assumptions required for the conduct of this parametric test were examined. These assumptions included normal distribution, homogeneity of variances, and sphericity. Table 2 indicates the results of repeated measures multivariate analysis of variance on the pre-test, post-test, and follow-up in terms of attitude towards mathematics and mathematical scores for the experimental and control groups.

Table 2: Repeated measures multivariate analysis of variance for the impacts between participants

Variable	Effect	Test	Value	F	Df Hypothesis	Df Error	Sig.	Effect size
Fear	Time	Wilks Lambda	0.297	10.32	2	49	0.001	0.25
	Time*Group	Wilks Lambda	0.354	9.41	2	49	0.001	0.24
Important	Time	Wilks Lambda	0.480	7.58	2	49	0.001	0.22
	Time*Group	Wilks Lambda	0.706	4.72	2	49	0.012	0.13
Motivation	Time	Wilks Lambda	0.415	8.46	2	49	0.001	0.23
	Time*Group	Wilks Lambda	0.124	13.82	2	49	0.001	0.32
Pleasure	Time	Wilks Lambda	0.862	2.37	2	49	0.077	0.07
	Time*Group	Wilks Lambda	0.795	6.04	2	49	0.001	0.20
Math Score	Time	Wilks Lambda	0.047	3.25	2	49	0.001	0.58
	Time*Group	Wilks Lambda	0.088	21.18	2	49	0.001	0.43

As it can be observed in Table 2, the time factor has made a significant difference between the pre-test and post-test scores of fear (P<0.01), importance (P<0.01), motivation (P<0.01), and math score (P<0.01). However, no significant difference was observed between the pre-test and post-test scores of pleasure (P>0.05). In addition, the interaction of time and group effect was revealed to be significant in components such as fear (P<0.01), importance (P<0.05), motivation (P<0.01), pleasure (P<0.01), and math score (P<0.01). This means that the experiment has made significant changes in these variables.

Table 3 shows the results of repeated measures ANOVA for pre-test, post-test, and follow-up test scores in components of attitudes towards mathematics and math scores for the experimental and control groups.

Table 3: Repeated measures ANOVA results for the impacts between participants

Variable	Source of changes	Sum of squares	Df	Mean Square	F	Sig.	Effect size
Fear	Time	125.13	1	71.46	12.87	0.001	0.26
	Time*Group	102.64	1	51.37	10.04	0.001	0.21
Important	Time	243.72	1	127.45	23.67	0.001	0.38
	Time*Group	120.36	1	62.28	11.52	0.001	0.24
Motivation	Time	146.29	1	79.63	17.41	0.001	0.30
	Time*Group	246.33	1	130.48	24.60	0.001	0.40
Pleasure	Time	116.72	1	63.12	3.58	0.036	0.10
	Time*Group	251.90	1	137.24	7.06	0.001	0.16
Math Score	Time	287.53	1	145.06	29.37	0.001	0.52
	Time*Group	197.14	1	100.62	20.72	0.001	0.34

As it is indicated in Table 3, the time factor (pre-test to post-test) has been found to be significant in fear (P<0.01), importance (P<0.05), motivation (P<0.01), pleasure (P<0.05), and math score (P<0.01). In other words, the changes in the experimental group have been significant over time. Similarly, the interaction of time and group has been also significant in components in these variables. In other words, the changes over time were significantly different between the two groups. Therefore, the above results may lead one to arrive at the conclusion that educational intervention will significantly result in the improvement of attitudes towards mathematics and increase of math scores.

Figure 1 confirms the fact that the experimental group receiving the educational intervention has obtained considerably higher scores regarding the improvement of attitudes towards math scores than the control group in the course of the study. On the other hand, the mean score of the control group has declined following the follow-up stage. In addition to visual inspection of the graphs, the effectiveness and impact factor reflect the significant and remarkable increase in attitudes towards mathematics in the experimental group. Figure 1 shows the changing process in attitudes towards math scores in the experimental and control groups more precisely.

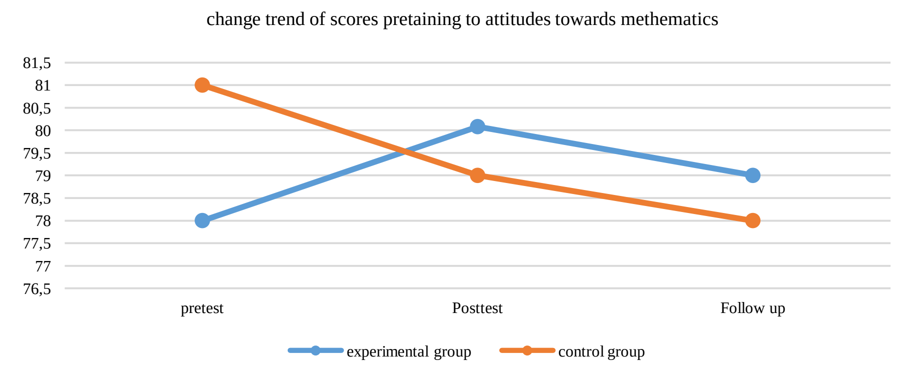

Fig. 1: Change trend of mean scores between the two groups in terms of attitudes towards mathematics in pre-test, post-test, and follow-up stages

Figure 2 also indicates that the experimental group receiving the educational intervention gained significantly higher math scores than the control group. On the other hand, the mean score of the control group has not experienced a significant increase after the follow-up stage. The effectiveness and impact factor suggest the significant increase of the experimental group's math scores.

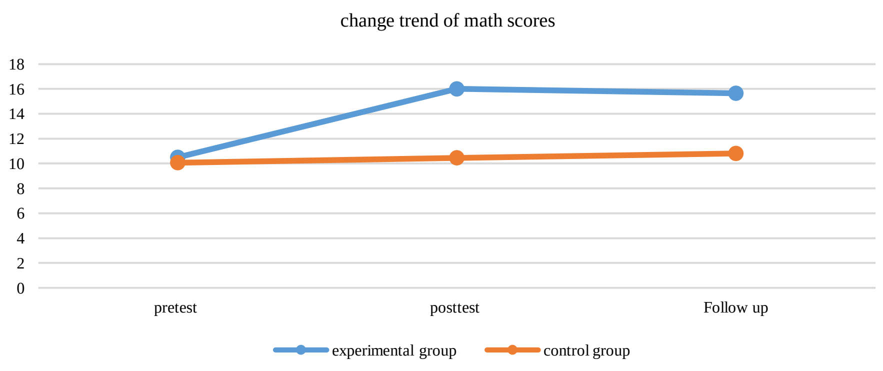

Fig. 2: Change trend of mean scores of math between the two groups in pre-test, post-test, and follow-up stages

5 Conclusion

The results of data analysis showed that metacognitive training and short-term and daily math practice of mathematical problem solving were significantly effective in the improvement of mathematical academic achievement positive attitudes among the junior high school students. These findings are consistent with those of the studies done by Rapport et al. (2013), Passolunghi et al., (2016), Witt (2011), and Bugden, DeWind & Brannon (2016). The children having difficulty in learning mathematics also encounter difficulty in applying the principles of metacognition. On the other hand, metacognitive training will naturally lead to the improvement of mathematical performance in the children having difficulty in in learning mathematics since metacognition organizes and regulates the cognition and learning process. Another reason that proves the necessity of metacognition training to the students is that metacognitive process in these children is not fulfilled automatically unlike normal children; thus, they need to compensate for this shortcoming by training and teaching (Schneider, & Artelt, 2010). Since the time mathematics educators have found that non-cognitive aspects of problem-solving performance are due to the importance of its cognitive aspects, metacognition, meaning knowledge and cognitive control, has attracted much attention of the research community of mathematics education. Therefore, interest in the study of the role of metacognition in mathematical problems is quite useful (Kaune, 2006).

Metacognition training is effective in the improvement of students' attitudes in addition to the creation of some skills regarding students' reading styles. This is so because students learn that it is possible to look at the issue be a fresh and new approach and to use modern methods to establish a connection and link with the problems. In addition to the occurrence of this attitude in mathematics and its performance, this attitude will also come effective in people as well because the metacognitive ability is a general quality that positively influences people's emotions, cognition, and behaviors in addition to dealing with mathematical problems.

Daily math problem solving in a short time has some benefits for students. They solve only 3 or 4 math problems every day that is not a boring activity. On the other hand, this method of problem solving gradually leads to a large amount of learning activities (21 to 28 math problems per week, 84 to 112 ones per month, and 168 to 224 ones every two months). This is a reality that rarely happens to students weak in academic achievement who do this volume of practices in the mentioned short time. Another positive aspect of this model of math exercise is that students learn math skills gradually and this leads to deep understanding of the problems that prevents forgetting. As the research findings of the present study suggest, short-term practice of mathematical problem solving leads to students' increased scores in academic achievement tests. The current research findings suggest that the increase of math scores improves positives attitudes towards mathematics. This finding is in line with the findings of previous studies wherein it was found that there is a significant relationship between attitudes towards mathematics and academic achievement (Goodykoontz, 2009; Pimta et al., 2009; Bassant, 1995; Hembee, 1990; Lyons & Beilock, 2012; and McLeod, 1988).

It seems that daily interaction with the mathematical course books and success in mathematical problem solving bring about positive attitudes towards mathematics. Success is pleasurable, eliminates fear of math exam, motivates students for greater achievements, and eventually leads to the improvement of students' mathematics scores and attitudes towards mathematics. Attitudes towards mathematics originate from factors such as performance, grades, concerns and worries, abilities, and self-efficacy, which can be expected to improve student performance. These attitudes subsequently promote some students' dimensions such as self-efficacy, self-esteem, and self-confidence. Finally, it can be concluded that metacognition training and short-term daily practice of mathematics are effective in students' mathematical attitudes and performance. In this way, teachers are recommended to become familiar with these concepts and methods and implement these training methods in the classroom to improve student performance.

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