

## **A Psychological Model for Mathematical Problem Solving based on Revised Bloom Taxonomy for High School Girl Students**

HAJIBABA, Maryam

School of Mathematical Science, Ferdowsi University of Mashhad, Azadi Square,  
Mashhad 9177948974, Iran; Email: m\_hajibaba2005@yahoo.com

RADMEHR, Farzad\*

School of Mathematical Sciences, Ferdowsi University of Mashhad, Azadi Square,  
Mashhad 9177948974, Iran; Email: fradmehr@asu.edu

ALAMOLHODAEI, Hassan

School of Mathematical Science, Ferdowsi University of Mashhad, Azadi Square,  
Mashhad 9177948974, Iran; Email: alamolhodaiei@yahoo.com

(Received August 30, 2011; Revised June 9, 2013; Accepted September 30, 2013)

The main objective of this study is to explore the relationship between psychological factors (*i.e.* math anxiety, attention, attitude, Working Memory Capacity (WMC), and Field dependency) and students' mathematics problem solving based on Revised Bloom Taxonomy. A sample of 169 K11 school girls were tested on

- (1) The Witkin's cognitive style (Group Embedded Figure Test).
- (2) Digit Span Backwards Test.
- (3) Mathematics Anxiety Rating Scale (MARS).
- (4) Modified Fennema-Sherman Attitude Scales.
- (5) Mathematics Attention Test (MAT) , and
- (6) Mathematics questions based on Revised Bloom Taxonomy (RBT).

Results obtained indicate that the effect of these items on students mathematical problem solving is different in each cognitive process and level of knowledge dimension.

*Keywords:* working memory capacity, math attention, math anxiety, math attitude, math problem solving

*MESC Classification:* D64

*MSC2010 Classification:* 97D60

---

\* Corresponding author

## INTRODUCTION

There is a strong movement in education to incorporate problem solving as a key component of the curriculum (Kirkley, 2003). The need for learners to become successful problem solvers has become a dominant theme in many national standards (AAAS, 1993; NCTM, 1989, p. 48–50; NCTM, 1991). Regarding assessing students math problem solving, the Revised Bloom Taxonomy is a useful tool. Two-dimensional Taxonomy Table emphasizes the need for assessment practices to extend beyond discrete bits of knowledge and individual cognitive processes to focus on more complex aspects of learning and thinking. It also provides a way to better understand a broad array of assessment models and application. Two dimensions to guide the processes of stating objectives and planning and guiding instruction leads to sharper, more clearly defined assessments and a stronger connection of assessment to both objectives and instruction. The power of assessments, regardless of whether they take the form of a classroom quiz, a standardized test, or a statewide assessment battery, resides in their close connection to objectives and instruction. The Taxonomy Table is a useful tool for carefully examining and ultimately improving this connection (Airasian & Miranda, 2002; Radmehr & Alamolhodaei, 2010).

According the importance of math problem solving the present study was carried out by the authors to study mathematical problem solving in term of some psychological factors (*i.e.*, mathematics anxiety, mathematic attitude, mathematics attention, working memory capacity and field dependency) based on RBT. It seems to be more beneficial to describe the historical background of these items and Revised Bloom Taxonomy before introducing research framework.

## HISTORICAL BACKGROUND

### **Revised Bloom Taxonomy**

Recognizing some limitations of Bloom's taxonomy (cf. Bloom, Engelhart, Furst, Hill & Krathwohl, 1956), a group of cognitive psychologist, curriculum and instructional researchers revised this taxonomy (Anderson *et al.*, 2001). Smith, Wood, Coupland & Stephen (1996) suggested some modifications to make it compatible with the purpose of assessing students' understanding in mathematics. A notable weakness in the original Bloom's taxonomy was the assumption that cognitive processes are ordered on a single dimension of simple to complex behavior (Furst, 1994). Moreover, the structure of the original taxonomy was a cumulative hierarchy, because the classes of objectives were arranged in order to increasing hierarchy. It was cumulative because each class of behaviors

was presumed to include all the behaviors of the less complex classes (Kreitzer & Madaus, 1994). This means that the mastery of each simpler category was prerequisite to mastery of the next more complex one (Krathwohl, 2002). In other words, Bloom identified six levels within the cognitive domain, from simple recall or recognition of facts, as the lowest level, through increasing more complex and abstract mental levels, to the highest order which is classified as evaluation.

Anderson *et al.* (2001) made some apparently minor but actually significant modifications, which came up with remembering, understanding, applying, analyzing, evaluating and creating. The six major categories in the original taxonomy were changed from noun to verb forms in the revised version. As the taxonomy reflects different forms of thinking and thinking is an active process, verbs were used rather than nouns. RBT employs the use of 24 verbs that create collegial understanding of student behavior and learning outcome.

The subcategories of the six major categories were also replaced by verbs and subcategories were recognized. The lowest level of the original version, knowledge was renamed and become remembering. Comprehension and synthesis were re-titled to understanding and creating; respectively, in order to better reflection of the nature of the thinking defined in each category.

**Table1.** The Two Dimensional Taxonomy Table\*

The Knowledge Dimension	1. Remembering	2. Understanding	3. Applying	4. Analyzing	5. Evaluating	6. Creating
A. Factual Knowledge						
B. Conceptual Knowledge						
C. Procedural Knowledge						
D. Meta-cognitive Knowledge						

\* Adapted from Anderson et al., 2001

The most considerable change in the RBT is the movement from one to two dimensions, which is the consequence of adding products. The Revised Bloom Taxonomy divides the noun and verb components of the original knowledge into two separate dimensions: the knowledge dimension (noun aspect) and the cognitive process dimension (verb aspect) (Krathwohl, 2002). As represented in Table 1, the intersection of the knowledge and cognitive process categories form 24 separate cells. The knowledge dimension on the side is comprised of four levels that are defined as factual, conceptual, procedural and

metacognitive. The cognitive process dimension across the top of the grid consists of six levels that are defined as Remember, Understand, Apply, Analyze, Evaluate, and Create. Each level of both dimensions of the table is subdivided.

As has been indicated, the above table has two dimensions: the knowledge dimension as the vertical axis and the cognitive process dimension as the horizontal ones. The intersections of the two axes form the cells. Rows represent the noun(s) or noun phrases in the objectives whereas columns represent the verb(s) in the objective. This table emphasizes to focus on more complex aspects of learning and thinking. The cognitive process dimension considers the need of finding ways for valid and reliable assessment of the higher order and metacognitive process. Knowledge of cognitive strategies, cognitive task and self not only requires different ways of thinking about assessment, but in the letter case, reintroduces the need to engage in affective assessment (Airasian & Miranda, 2002, p. 249).

In concern to mathematical problem solving Radmehr & Alamolhodaei (2010) found that in each category of knowledge dimension (*i.e.*, factual, conceptual, procedural, metacognitive) students performed better in remembering mathematics objective than each five parts, after that they performed better in applying mathematical objective and then understanding mathematics objectives. But generally there were not significant differences between mathematical performance in analyzing and evaluating mathematics objectives. Finally, they were less successful in creating mathematical objectives. The researchers found that students' mathematical performance were decreased regularly. The students' mathematical performances were better in cells related to applying questions than understanding questions. This could be happened because students may be solving many mathematics problems without understanding the concepts. They just use the algorithms that suitable for the questions. Moreover, they seen that many students can solve questions about limit and derivative without knowing the concept of them

### **Cognitive Style (Field Dependency)**

Field dependence/independence (FDI) or disembedding ability cognitive style represents the ability of students to disembed information (cognitive restructuring) in a variety of complex and potentially misleading in structural context (Witkin, Moore, Goodenough & Cox, 1977; Collings 1985; Niaz, 1996). FDI is a widely used dimension of cognitive style in education which specifies learner's mode of perceiving cognitive restructuring, thinking, problem solving, and remembering (Witkin & Goodenough, 1981; Saracho, 1998, Alamolhodaei, 2009, Amani, Alamolhodaei & Radmehr, 2011).

According to Witkin & Goodenough (1981), people are termed field-independent (FI) if they are able to abstract an element from its context or background field. In that case,

they tend to be more analytical and approach problems in a more analytical way. Field-dependent (FD) people, on the other hand, are more likely to be better at recalling social information such as conversation and relationships. They approach problems in a more global way by perceiving the total picture in a given context.

Several researchers have demonstrated the importance of field dependency in science education and mathematical problem solving, in particular word problems (Witkin & Goodenough 1981; Johnstone & Al-Naeme, 1991; Johnstone & Al-Naeme, 1995; Alamolhodaei 1996; Srivastava, 1997; Ekbai & Alamolhodaei 2000; Alamolhodaei 2002; Alamolhodaei 2009; Mousavi, Radmehr, Alamolhodaei, 2012). It was found that FI students tend to get higher results than FD students in calculus problem solving at university level. Moreover, school students with FI cognitive style achieved much better results than FD ones in mathematical problem solving, particularly word problems.

### **Mathematics Attitude**

Mathematics attitude should be viewed as a predisposition to respond in an unfavorable or favorable way to mathematics. By accepting this view, mathematics attitude includes relevant beliefs, behavior and attitudinal or emotional reactions. Researches indicated that, there is a positive relation between mathematics attitude and mathematics achievement (Ma & Kishor, 1997; Saha, 2007; Thomas, 2006). The attitudes of students towards lesson is not only effecting the success or interests but also effecting future field, lessons, jobs selection of students (Koca & Sen, 2006). According to literature, attitude can predict achievement and that achievement, in turn, can predict attitude (Meelissen & Luyten, 2008, Fardin, Alamolhodaei & Radmehr, 2011). Especially some students have quite negative opinions about math because of negative behaviors of teachers or wrong experiences. These students have prejudice such as math's is complex and only those who have a talent for math's can achieve it. This situation is continuing during the school years and students' self-confidence is disappearing. Changing the negative attitudes of students into positive can be provided if the teachers increase the positive experiences of students towards Math's.

### **Mathematics Anxiety**

Mathematics anxiety is first introduced as a distinct construct by Dreger and Aiken in 1957 and it has been suggested as a subject specific form of anxiety (Baloğlu & Zelhart, 2007). Atkinson (1988) defined mathematics anxiety as “a sequence of cognitive, affective, and behavioral responses to a perceived self-esteem threat which occurs as a response to situations involving mathematics” (p. 3).

Mathematics anxiety, however, is a key affective variable can impede both learning

(Fiore, 1999; Stuart, 2000) and performance (Richardson & Suinn, 1972; Wigfield & Meece, 1988; Hembree, 1990; Ho *et al.*, 2000) in mathematics and, hence, can have deleterious effects on schooling (Felson & Trudeau, 1991), occupational (Trice & Ogden, 1987) and overall life outcomes.

Also some studies have, in fact, associated mathematics anxiety with student's prior experiences of formal instruction in mathematics (Harper & Daane, 1998; Jackson & Leffingwell, 1999).

It may be symptomatic of an inability to handle frustration, excessive school absences, poor self-concept, internalized negative parental and teacher attitudes toward mathematics, and an emphasis on learning mathematics through drill without "real" understanding (Norwood, 1994; Singh & Broota, 1992).

A number of studies have been carried out over the last few decades on math anxiety investigating its effects upon mathematical problem solving across all grade levels, k-college. They all revealed that math anxiety is often associated with low performance in mathematical activity and in particular solving math problems (*e.g.*, Hembree, 1990; Baloglu & Kocak, 2006; Alamolhodaie, 2009, Pezeshki, Alamolhodaie & Radmehr 2011).

### **Math Attention**

Math is a way of thinking and requires a great deal of attention, particularly when multiple steps are involved in the problem solving process (Amani, Alamolhodaie & Radmehr, 2011). During math instruction, students who have attention difficulties often miss important parts of information. Without this information, students have difficulty trying to implement the problem solving process they have just learned when Z-demand (amount of information processing required by the math task) was increased; more attention would be needed to cope with its complexity.

At the heart of math attention is the issue of how many tasks can be done at the same time to reach a solution. Taking notes and understanding a mathematical lecture are two different activities, but related to each other. Why is it so difficult to do both simultaneously? Is it because one can process only one source of information at a time? According to Ellis & Hunt (1993), attention is the process allocating the resources or capacity to various inputs, attention is then important in determining which mathematical tasks are accomplished and how well the tasks are performed. Attention and consciousness have a close relationship that developed from the observation that conscious processing capacity is quite limited. In addition, the relationship between attention and intelligence has been investigated (Schweizer & Moosbrugger, 2004)

Rather complex relationship between perception, attention and consciousness in doing mathematical task could be increased students difficulties. Mathematical attention is a

cognitive functioning which allocates the math information and Z-demands of tasks to a different level of consciousness. Therefore, with the increasing of consciousness, the mathematical attention would be developed. The process of attention could be help students to meaningful learning of mathematical activities. On the contrary, inattention is most commonly and widespread problems for learners. Inattention is a risk factor for poor mathematics achievement, and low Working Memory (WM) is a causative (Tannock, 2008).

Based upon Alloway *et al.* (2009) findings, teachers typically judged the children with low WMC were highly inattentive and having poor attention span and high levels of distractibility. These students often made careless mistakes, particularly, in solving problems in every day classroom activities and making high risk of poor academic progress, in particular, in math.

### **Working Memory Capacity**

Working Memory (MC) refers to a mental workspace, involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks (*e.g.*, mathematical processing) (Raghubar, Barnes & Hecht, 2010). It operates over a few seconds, and it allows us to focus our attention, resist distractions and guide our decision making. Low working memory is a barrier to both the efficiency and learning of both calculation and higher level problem solving (Klingberg, 2008). Without working memory skills, learners would not be able to carry out some kinds of complex mental activity in which they have to both keep in mind some information while individual differences in the capacity of working memory appear to have important consequences for students' ability to acquire knowledge and new skills. A number of studies have been discussed that WM skills impact learning throughout the school years (Alloway, 2006). There is growing evidence that WM may be important for mathematical activities and mathematical deficits could result from poor WM abilities (Wilson & Swanson, 2001; Holmes & Adam, 2006; Alamolhodaei, 2009). This view is supported by some studies that WM is available indicator of mathematical disabilities in the first years of formal schooling (Gersten, Jordan & Flojo, 2005). In addition, low WM capacity have been found to be closely related to poor computational skills (Wilson & Swanson, 2001) and poor performance on arithmetic word problems (Swanson & Saches-Lee, 2001). According to Alamolhodaei (2009), based on the students performance in math exams (word problems and ordinary exam), the high working memory students achieved significantly higher results than low WM ones. Visuo-spatial memory as a sub-component of WM (Logic, 1995) is also closely linked with mathematical skills. It has been suggested that visuo-spatial memory functions as a mental blackboard, supporting number representation, such as place value and

alignment in columns, in counting and arithmetic (McLean & Hitch, 1999; D'Amico & Gharnera, 2005).

### **Research Framework**

This study is a part of a project release in School of Mathematical Sciences of Ferdowsi University of Mashhad. In this project a psychological model will be discussed for students mathematical problem solving based on RBT in six different levels (K5, K7, K11, University Calculus, Algebra1, and Analysis1 for mathematics students). This paper introduces the results obtained for high school students (K11). According to previous studies in this field, these factors contributed to mathematical problem solving. But there is no evidence about the effects of each psychological factor on students' mathematical problem solving in different cognitive process or knowledge dimension.

When researchers replace their mathematics questions to the questions that consist of RBT 24 cells, they may find more insight of the level of students' understanding. This knowledge could help them to be familiar with mathematics education issues and students' difficulties (Radmehr & Alamolhodaie, 2010). So this type of question for carrying this study has been chosen. The main aim of the present study is to investigate the relationship between each of these psychological factors and students' mathematical problem solving based on RBT. Thus the main question addressed here is: Is there any relationship between each of these psychological factors and students mathematical problem solving in different cells of RBT? In an attempt to answer this question the following objectives were sought:

The first objective of the study was to discover whether there was any relationship between students' mathematical problem solving in each knowledge categories (*i.e.*, factual, conceptual, procedural, and metacognitive) of Revised Bloom Taxonomy and each of these psychological factors.

The second objective was to find whether there was any relationship between students' problem solving in each cognitive process (*i.e.*, remembering, understanding, applying, analyzing, evaluating, and creating) of RBT and each of these psychological factors.

## **METHOD**

### **Participants**

169 K11 school girls were selected from high schools of Mashhad (Khorasan Province) using random multistage stratified sampling design.

### **Procedures**

The research instruments were:

- (1) Mathematics questions based on Revised Bloom Taxonomy
- (2) Digit Span Backwards Test (DBT)
- (3) Cognitive style (FD/FI) test
- (4) Mathematics Anxiety Rating Scale (MARS)
- (5) Modified Fennema-Sherman Attitude Scales
- (6) Mathematics Attention Test (MAT)

### **Mathematics questions based on Revised Bloom Taxonomy**

Our test had 120 mathematics questions from K11 calculus book based on RBT that has been used in Radmehr & Alamolhodaie (2010) study on students' mathematical problem solving for K11 students. Each 5 questions were examined one of the cells in Revised Bloom Taxonomy. We have 24 cells so 120 questions are needed to cover all of them. The researchers mentioned that each question may be incorporates several levels of the taxonomy at once as Green (2010) presents in his paper. In this research we hypothesis that (without loss of generality) each question, examined just one cell. Participants answered this test in 3 parts that each one contains 40 questions:

Part one examined remembering and understanding cells (including: remembering factual knowledge, conceptual knowledge, procedural knowledge, metacognitive knowledge, understanding factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge).

Part two examined applying and analyzing cells (including: applying factual knowledge, conceptual knowledge, procedural knowledge, metacognitive knowledge, analyzing factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge).

Part three examined evaluating and creating cells (including: evaluating factual knowledge, conceptual knowledge, procedural knowledge, metacognitive knowledge, creating factual knowledge, conceptual knowledge, procedural knowledge and metacognitive knowledge).

Here are some typical questions of this exam.

**Sample Question 1.** Which method is better for solving this equation?

$$x^2 - \frac{2}{3}x - \frac{35}{9} = 0$$

- |                      |                          |
|----------------------|--------------------------|
| 1) Delta method      | 2) Perfect square method |
| 3) Drawing the graph | 4) Factorization method  |

Students for answering this question should remember the methods that they can solve quadratic equations. According to the structure of the knowledge dimension of the Revised Taxonomy, strategic knowledge is metacognitive knowledge therefore according to the equations and its coefficient, students should choose perfect square method so this question is a remember metacognitive knowledge question. For answering this question, students don't need to solve the equation; they should remember strategies and choose the best one. Also they should analyze factual knowledge to choose the best strategies. But in this study, researchers for each question choose just one cell. The chosen cell for each question is the important part of solution that students should done to solve the problem. As can be seen from this question the important part is remembering metacognitive knowledge because analyzing factual knowledge has routine algorithm. The key to answer this question is to remember when we should choose each strategy. In other example that can be seen below, researchers describe the main point of the problem that students should consider to solve the question.

**Sample Question 2.** Which one is the symmetry axis of even functions and which one is the symmetry center of odd functions?

- 1) X-axis, origin of coordinate                      2) Y-axis, origin of coordinate  
 3) Line:  $y = x$ , point:  $(-1, -1)$                       4) X-axis, point:  $(-1, -1)$

Knowledge of terminology, according to the structure of the knowledge dimension of the Revised Taxonomy is a factual knowledge and students for answering this question should know the definition of even and odd functions and also should know the definition of symmetry center and axis so interpreting and inferring these definition lead students to choose, choice 2 also according to the structure of the cognitive process of the RBT interpreting and inferring are part of understanding so this question is a understanding factual knowledge question

**Sample Question 3.** Consider that profit or loss of a factory is a function of

$$t: f(t) = 2t^2 - 4t - 6 .$$

When the factory doesn't have any profit or loss?

- 1)  $-1, 1$                       2)  $3, 1$                       3)  $-1, 3$                       4)  $-3, -1$

In RBT conceptual knowledge defined as the interrelationships among the basic elements within a larger structure that enable them to function together and also it has Knowledge of theories, models, and structures so students for answering this questions should apply theories about where functions are equal to zero therefore this is a apply

conceptual knowledge questions.

**Sample Question 4.** In the equation  $|x - a| + |x - b| = k > 0$ , how many of these statements are true?

- A) If  $k > |b - a|$  then the equation has two roots.
- B) If  $k = |b - a|$  then the equation has an infinite root
- C) If  $k < |b - a|$  then the equation has no root.

- 1) 0                      2) 1                      3) 2                      4) 3

For answering this question, students should differentiating and organizing this equation  $|x - a| + |x - b| = k > 0$  and should know its graph to answer it. For drawing its graph, students should know the concept of absolute value and its graph; on the other hand, organizing and differentiating are part of analyze (according to cognitive process dimension) so this is an analyze conceptual knowledge question.

**Sample Question 5.** Which one is equal to  $y = x + 2$ ?

- 1)  $y = \frac{x^2-4}{x-2}$
- 2)  $y = 2 + \sqrt{x^2}$
- 3)  $y = \frac{x^3+2x^2+x+2}{x^2+1}$
- 4)  $y = \sqrt{x^2 + 4x + 4}$

According to the knowledge dimension of the Revised Bloom Taxonomy, procedural knowledge defined as How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. Students for answering this question should have the ability of evaluating (consist of checking and critiquing), domain of these 5 functions and their equations to determine equal functions so this is a procedural knowledge question

**Sample Question 6.** In which condition  $f : R \rightarrow Q$  is continuous?

- 1) When the range of  $f$  are natural numbers.
- 2) When  $f$  is an injective function.
- 3) When  $f$  is a surjective function.
- 4) When  $f$  is a constant function.

***Digit Span Backwards Test (DBT)***

For measuring students' working memory capacity, DBT has been showed to be the most suitable test (Case 1974; Alamolhodaei, 2009; Raghobar & Alamolhodaei, 2010; Pezeshki, Alamolhodaei & Radmehr 2011). To this end, the digits were read out by an expert and the students were asked to listen carefully, then turn the number over in their

mind and write it down from left to right on their answer sheets. WMC was originally has five plus or minus two storage unit as Pascual Leoni described.

### ***Mathematics Anxiety Rating Scale (MARS)***

The level of anxiety was determined by the score attained on the Math Anxiety Rating Scale (MARS), which has been recently developed in the School of Mathematical Sciences of Ferdowsi University of Mashhad. The MARS for this research was newly designed by the researcher according to the inventory test of Ferguson (1986). It consists of 32 items, and each item presented an anxiety arousing situation. The students decided the degree of anxiety and abstraction anxiety aroused using a five rating scale ranging from very much to not at all (5–1). Cronbach's alpha, the degree of internal consistency of mathematics attention test items for this study was estimated to be 0.90.

### ***Cognitive style (FD/FI) Test***

The independent variables were cognitive style and the position of a learner on each of the learning style dimensions (FD and FI) was determined using the Group Embedded Figures Test (GEFT). In this test, subjects are required to disembed a simple figure in each complex figure. There are 8 simple and 18 complex figures, which make up the GEFT. Each of the simple figures is embedded in several different complex ones. Students' cognitive styles were determined according to the criterion used by other researchers (Case 1974; Alamolhodaie 1996; Alamolhodaie 2009; Mousavi, Radmehr & Alamolhodaie, 2012).

### ***Modified Fennema-Sherman Attitude Scales***

In an effort to assess students' attitudes towards math, Elizabeth Fennema and Julia A. Sherman constructed the attitude scale in the early 1970's. The scale consists of four subscales: confidence scale, usefulness scale, teacher perception scale and a scale that measures mathematics as a male domain. Each scale consists of 12 items of which six measure a positive attitude and the remaining measure a negative attitude. This scale could provide useful information about that student's attitude(s) towards math. Because this scale was originally designed many years ago and the subtle meanings and connotations of words have changed since, Doepken, Lawsky and Padwa were modified it. The authors used the modified version of the test which can be obtained from the URL given below:

URL: <http://www.woodrow.org/teachers/math/gender/08scale.html>

### ***Mathematics Attention Test (MAT)***

The level of math attention was determined by an unpublished attention test which has been developed in the School of Mathematical Sciences of Ferdowsi University of Mash-

had. In this task students respond to 25 questions which arranged according to Likert scale from very little to too much. Cronbach's alpha, the degree of internal consistency of mathematics attention test items was estimated to be 0.86. Here are some typical questions of this exam:

How much attention do you have in each situation?

Question Number	Question
1	When the subjects are offered by teacher in the classroom.
2	When studying the math lessons that you have been learned.
3	When the math teacher is teaching and you need to write and listen simultaneously.
4	When studying and learning mathematics in a group.
5	When the math course materials are to be tangible and concrete.
6	When teacher directly monitors the process of your math problem solving.
7	When the math course materials are to be tangible and concrete.
8	When the math course materials are to abstract and you have no idea about it in your mind.

## RESULTS

### *Cognitive Style & Mathematical problem solving based on RBT*

In order to maximize the effect of cognitive style, the results of FD and FI group were compared, and the intermediate group (FInt) was ignored. (Alamolhodaie, 2009) Based upon T-test for independent samples of FD and FI on mean scores of mathematical problem solving in different cognitive process of RBT, significant differences were found between two groups of cognitive styles for Remembering, Understanding and creating math objectives as shown in Table2. For other cognitive process, significant difference wasn't obtained between these two groups nevertheless according to Table 2 FI students obtained higher score than FD students in Applying, Analyzing and evaluating math objectives. Concerning to knowledge dimension, T-test reported a significant difference between FI and FD learners in terms of students' mathematical problem solving in conceptual, procedural and metacognitive knowledge. For factual knowledge no significant difference was reported while according to Table 2 FI students got a better score in mathematical questions related to factual knowledge.

**Table 2.** Students' mathematical problem solving based on RBT & Cognitive Style

	Remembering math objective	Understanding math objective	Applying math objective	Analyzing math objective	Evaluating math objective	Creating math objective	Math factual knowledge	Math conceptual knowledge	Math procedural knowledge	Math metacognitive knowledge
P-values	0.007**	0.011**	0.537	0.194	0.118	0.068*	0.145	0.014**	0.009**	0.092*
FD students' Mean score	11.26	6.25	9.38	5.45	5.58	3.08	13.98	11.08	7.28	9.07
FD students' SD	3.27	3.32	2.66	2.62	2.49	2.12	3.69	3.82	3.03	3.31
FI students' Mean score	12.93	7.85	9.72	6.07	6.32	3.77	14.95	13.00	8.80	10.13
FI students' SD	3.19	3.36	3.21	2.48	2.51	1.78	3.87	4.28	2.88	3.10

\* Difference between FD and FI students in mathematical performance is significant at 0.1 levels

\*\* Difference between FD and FI students in mathematical performance is significant at 0.05 levels

***Working memory Capacity & Mathematical problem solving based on RBT***

The Pearson's correlation between students mathematical problem solving and students' WMC was significant for remembering (at .05 levels), analyzing (at .01 levels), evaluating (at .1 levels) and creating (at .05 levels) math objectives. For understanding and applying math objective no significant correlation were obtained according to Table 3 while the correlation between students mathematical problem solving and WMC was positive.

For knowledge dimension , significant correlation between students mathematical problem solving and WMC was obtained in each level of knowledge dimension except metacognitive knowledge according to Table 3. Although the correlation between this item and WMC was positive ( $r = .130$ ).

***Math Attention & Mathematical problem solving based on RBT***

The Pearson's correlation between students mathematical problem solving and students' math attention was significant for remembering, understanding and analyzing math objective according to Table 3 but for applying, evaluating and creating math objective, no significant correlation were reported although the correlation between these item and math attention were positive.

Concerning to knowledge dimension, significant correlation between each level of knowledge dimension obtained and math attention was obtained except factual knowledge as shown in Table 3. More over the correlation between students' math attention and students mathematical problem solving related to factual knowledge was positive.

***Math Anxiety & Mathematical problem solving based on RBT***

The Pearson's correlation between students' mathematical problem solving and students' math anxiety was significantly negative for each cognitive process as shown in Table 3. Also for knowledge dimension, significant negative correlation reported for each level of it at 0.01 levels.

***Math Attitude & Mathematical problem solving based on RBT***

The correlation between students' mathematical problem solving and students' math attitude was significant for each cognitive process except analyzing math objective as reported by Table 3 while for all level of knowledge dimension, significant positive correlation were obtained.

**Table 3.** Students' mathematical problem solving based on RBT & WMC & Math Attention & Anxiety & Attitude

	Remembering math objective	Understanding math objective	Applying math objective	Analyzing math objective	Evaluating math objective	Creating math objective	Math factual knowledge	Math conceptual knowledge	Math procedural knowledge	Math metacognitive knowledge
WMC	0.166**	0.112	0.097	0.260***	0.146*	0.178**	0.221***	0.188**	0.231***	0.130
Math Attention	0.185**	0.195**	0.117	0.155*	0.123	0.108	0.138	0.231***	0.211**	0.168*
Math Anxiety	-0.361***	-0.409***	-0.310***	-0.362***	-0.276***	-0.235**	-0.392***	-0.443***	-0.421***	-0.385***
Math Attitude	0.259***	0.214**	0.226***	0.130	0.185**	0.184**	0.243***	0.328***	0.227**	0.173**

\* Correlation is significant at the 0.1 level (2-tailed)

\*\* Correlation is significant at the 0.05 level (2-tailed)

\*\*\* Correlation is significant at the 0.01 level (2-tailed)

## DISCUSSION

According to previous studies in mathematics education, these psychological factors (*i.e.*, Math anxiety, attitude, attention, WMC, cognitive style) contributed to mathematical problem solving. But there is no evidence about the effects of each psychological factor on students' mathematical problem solving on different cognitive process or knowledge dimension. According to result of this study students mathematical problem solving in different cognitive process and knowledge dimension were negatively correlated to math anxiety. Findings of this study support previous claims that math anxiety could predict mathematical problem solving (*e.g.*, Hembree, 1990; Baloglu & Kocak, 2006; Alamolhodaei, 2009; Pezeshki, Alamolhodaei & Radmehr, 2011). Moreover the results of this study were shown that these negative correlations lie around all of cognitive process and in different levels of knowledge dimension. This could be the most remarkable finding of the present study.

Concern to attitude toward mathematics, finding of this research was supported the previous studies that there is a positive relation between mathematics attitude and mathematics achievement (Ma & Kishor, 1997; Saha, 2007; Thomas, 2006; Meelissen & Luyten, 2008; Fardin, Alamolhodaei & Radmehr, 2011). In addition this study revealed that, the effects of students' attitude towards mathematics on different cognitive process and level o knowledge are different. For cognitive process in lower level of thinking (*i.e.*, remembering, understanding, applying math objective) the correlation between math attitude and mathematical problem solving is greater than higher level of thinking such as analyzing math objectives. For knowledge dimension, researchers were seen that the correlation between math attitude and mathematical problem solving in metacognitive knowledge was lower than other part of knowledge.

For math attention that is a new term in research field of mathematics education, results of this study was the same with previous research of Alamolhodaei, Farsad & Radmehr (2011) that math attention may predict mathematical problem solving. More over this study shown that this relationship was in remembering, understanding and analyzing math objective may be more than other cognitive process. In knowledge dimension, researchers seen that this item doesn't significantly correlated to students mathematical problem solving related to factual knowledge.

Also for WMC, the results of this study was supported by previous research in this field that students with higher WMC have better performance in mathematical problems than lower ones. (*e.g.*, Alloway, 2006; Alamolhodaei, 2009; Raghubar, Barnes & Hecht, 2010). In addition, according to results of this study the effects of WMC on students mathematical problem solving was greater on analyzing math objectives than other parts;

and in knowledge dimension the effects of WMC on students math problem solving was superior in procedural knowledge.

In regard to field dependency ,finding of this study supported previous claims that FI students' showed better mathematical problem solving than FD ones. Moreover this study revealed that this difference was concern to cognitive process such as remembering, understanding and creating math objectives and for knowledge dimension, the difference was seen in all level of knowledge except mathematics questions related to factual knowledge.

The findings of this study get more insight about the relationship between each psychological factors and students mathematical problem solving. It determines the effects of each factor on students mathematical problem solving in different cognitive process and knowledge dimensions. As a mathematics teacher we should try to reduce students' math anxiety to perform better in all levels of cognitive process and knowledge dimension. Also we should change students' approach about mathematics to improve their performance in mathematical problem solving in different cells of RBT. Students with low WMC and FD style should be helped by teachers to show roughly the same mathematical performance as student students with high WMC and FI styles. Finally teachers should use strategies that students got the maximum math attention so they to perform better in mathematical problem solving in different cognitive process and knowledge dimensions.

As in usual with pioneering research, many questions could arise from this study, each of which may become a point of departure for the next research. The results of the present study are based upon female student samples. Consequently, further experiments are necessary perhaps under more specific conditions for finding more information, in particular for male students.

## REFERENCES

- Airasian, W. & Miranda, H. (2002). The role of assessment in The Revised Taxonomy. Theory into practice **41(4)**, 249–254. ERIC EJ667161
- Alamolhodaei, H. (1996). *A study in higher education calculus and students' learning styles*. Ph. D. Thesis. Glasgow, UK: University of Glasgow.
- \_\_\_\_\_ (2002). Students' cognitive style and mathematical word problem solving. *J. Korea Soc. Math. Educ. Ser. D* **6(2)**, 171–182. ME **2003a.00150**
- \_\_\_\_\_ (2009). A Working Memory Applied to Mathematical Word Problem Solving. *Asia Pacific Educational Review* **10(2)**, 183–192. ERIC EJ869821
- Alamolhodaei, H.; Farsad, N. & Radmehr, F. (2011). On the capacity of mathematics Attention: It's role on metacognition, math attitude, Field-dependency and mathematical problem solving.

*Preprint.*

- Alloway, T. P. (2006). How does working memory work in the classroom? *Educational Research Review* **1**(4), 134–139. ERIC EJ903186
- Alloway, T. P.; Gathercole, S. E.; Holmes, J.; Place, M. & Elliott, J. (2009). The diagnostic utility of behavioral checklists in identifying children with ADHD and children with working memory deficits. *Child Psychiatry & Human Development* **40**(3), 353–366. ERIC EJ842287
- Amani, A.; Alamolhodaei, H. & Radmehr, F. (2011). A gender study on predictive factors of mathematical performance of University students. *Educational Research*. **2**(6), 1179–1192
- American Association for the Advancement of Science [AAAS] (1993). *Benchmarks for science literacy*. New York: Oxford University Press. ERIC ED399180
- Anderson, L.; Krathwohl, R.; Airasian, P.; Cruikshank, K.; Mayer, R.; Pintrich, P.; Raths, J. & Wittrock, M. (Eds.) (2001). *Taxonomy for learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy*. New York, NY: Longman.
- Atkinson, R. T. (1988). *An exploration of the factors relating to the system of mathematics anxiety*. Unpublished doctoral dissertation. Stillwater, OK: Oklahoma State University.
- Baloğlu, M. & Koçak, R. (2006). A multivariate investigation of the differences in mathematics anxiety. *Personality and Individual Differences* **40**(7), 1325–1335.
- Baloğlu, M. & Zelhart, P. F. (2007). Psychometric properties of the revised mathematics anxiety rating scale. *Psychological Record* **57**(4), 593–611. ERIC EJ781798  
<http://opensiuc.lib.siu.edu/tpr/vol57/iss4/8/>
- Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H. & Krathwohl, D. R. (Eds.) (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain*. New York: David McKay.
- Case, R. (1974). Structures and strictures, some functional limitations on the course of cognitive growth. *Cognitive Psychology* **6**, 544–574.
- Collings, J. N. (1985). Scientific thinking through the development of formal operations: Training in the cognitive restructuring aspect of field-independence. *Research in Science & Technological Education* **3**(2), 145–152. ERIC EJ328746
- D'Amico, A. & Guarnera, M. (2005). Exploring working memory in children with low arithmetical achievement. *Learning and Individual Differences* **15**(3), 189–202. ERIC EJ698074
- Ekbai, A., & Alamolhodaei, H. (2000). *A study of the effectiveness of working memory and cognitive style on mathematical performance of (13-year-old) school boys*. M. A. Thesis, Tehran, Iran: Teacher Training University of Tehran.
- Ellis, H. & Hunt, R. (1993). *Fundamentals of Cognitive Psychology, Fifth Edition*. Brown & Benchmark, Dubuque, USA.
- Fardin, D.; Alamolhodaei, H. & Radmehr, F. (2011). A Meta-Analyse On Mathematical Beliefs and Mathematical Performance of Iranian Students. *Educ. Res.* **2**(4), 1051–1058.
- Felson, R. B. & Trudeau, L. (1991). Gender differences in mathematics performance. *Social Psy-*

- chology Quarterly* **54(2)**, 113–126.
- Ferguson, R.D. (1986). Abstraction anxiety: A factor of mathematics anxiety. *Journal for Research in Mathematics Education* **17(2)**, 145–150. ERIC EJ336474
- Fiore, G. (1999). Math-abused students: Are we prepared to teach them? *Mathematics Teacher*, **92(5)**, 403–406. ME 2000c.01623 ERIC EJ590287
- Frust, E. (1994). Bloom's Taxonomy: Philosophical and Educational Issues. In: L. Anderson and L. Sosniak (Eds.), *Bloom's Taxonomy: A Forty-Year Retrospective* (pp. 28–40). Chicago, IL: National Society for the Study of Education.
- Green, K. H. (2010). Matching Functions and Graphs at Multiple Levels of Bloom's Revised Taxonomy. *PRIMUS* **20(3)**, 204–216 ME 2010f.00339 ERIC EJ883248
- Gersten, R.; Jordan, N. C. & Flojo, J. R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities* **38(4)**, 293–304. ERIC EJ695624
- Harper, N. W. & Daane, C. J. (1998). Causes and reduction of math anxiety in preservice elementary teachers. *Action in Teacher Education* **19(4)**, 29–38. ME 1999f.03755 ERIC EJ572760
- Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education* **21(1)**, 33–46. ME 1990f.00800 ERIC EJ407520
- Ho, H.; Senturk, D.; Lam, A. G.; Zimmer, J. M.; Hong, S.; Okamoto, Y.; Chiu, S-Y.; Nakazawa, Y. & Wang, C-P. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *J. Res. Math. Educ.* **31(3)**, 362–379. ME 2005d.01400
- Holmes, G. & Adams J. (2006). Working memory and Children's Mathematical skills: Implications for mathematical development and mathematics Curricula. *Educ. Psychol.* **26(3)**, 339–366. ERIC EJ722163
- Jackson, C. D. & Leffingwell, R. J. (1999). The role of instructor in creating math anxiety in students from kindergarten through college. *Mathematics Teacher* **92(7)**, 583–586.
- Johnstone, A. H. & Al-Naeme, F. F. (1991). Room for scientific thought. *International Journal of Science Education* **13(2)**, 187–192. ERIC EJ443645
- \_\_\_\_ (1995). Filling a curriculum gap in chemistry. *International Journal of Science Education* **17(2)**, 219–232.
- Kirkley, J. (2003). *Principles for Teaching Problem Solving*. Bloomington, MN: Plato Learning. [www.plato.com/media/Technical-White%20Papers/2/Principles%20for%20Teaching%20Problem%20Solving.pdf](http://www.plato.com/media/Technical-White%20Papers/2/Principles%20for%20Teaching%20Problem%20Solving.pdf)
- Klingberg, T. (2005). *The concept of working memory*. Retrieved April 24, 2008 from [www.workingmemory.com](http://www.workingmemory.com).
- Koca, A. Ö. & Sen, A. I. (2006). The Reasons for Negative Attitudes of Elementary School Students towards Maths and Science Lesson. *Eurasian Journal of Education Research* **23**, 137–147.

- Krathwohl, D. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory into Practice* **41(4)**, 212–218. ERIC EJ667155
- Kreitzer, A. & Madaus, G. (1994). Empirical Investigations of the Hierarchical Structure of the Taxonomy. In: L. Anderson and L. Sosniak (Eds.), *Bloom's Taxonomy: A Forty year Retrospective* (pp. 64–81). Chiacago, IL: National Society for the Study of Education.
- Logie R. H. (1995). *Visuo-spatial working memory*. Mahwah, NJ: Lawrence Erlbaum.
- Ma, X. & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *J. Res. Math. Educ.* **28(1)**, 26–47. ME **1997f**.03693 ERIC EJ536673
- McLean, J. F. & Hitch, G. H. (1999). Working memory impairments in children with specific mathematics learning difficulties. *J. Exp. Child Psychol.* **74(3)**, 240–260. ME **2000d**.02653 ERIC EJ597717
- Meelissen, M. & Luyten, H. (2008). The Dutch gender gap in mathematics: Small for achievement, substantial for beliefs and attitudes. *Studies in Educational Evaluation* **34**, 82–93. ERIC EJ798123
- Mousavi, S.; Radmehr, F. & Alamolhodaei, H. (2012). The role of mathematical homework and prior knowledge on the relationship between students' mathematical performance, cognitive style and working memory capacity. *Electronic Journal of Research in Educational Psychology* **10(3)**. 1223–1248.
- National Council of Teachers of Mathematics [NCTM] (1989). *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics. ME **1996f**.03595 ERIC ED304336
- \_\_\_\_ (1991). *Professional Standards for Teaching Mathematics*. National Council of Teachers of Mathematics. Reston, VA: National Council of Teachers of Mathematics. ME **1991e**.00332 ERIC ED344779
- Niaz, M. (1996). Reasoning strategies of student in solving chemistry problems as a function of development level, functional M-capacity and disembedding ability. *International Journal of Science Education* **18(5)**, 525–541. doi:10.1080/0950069960180503
- Norwood, K. S. (1994). The effect of instructional approach on mathematics anxiety and achievement. *Sch. Sci. Math.* **94(5)**, 248–254. ME **1996a**.00078 ERIC EJ500238
- Pezeshki, P.; Alamolhodaei, H. & Radmehr, F. (2011). A predictive model for mathematical performance of blind and seeing students. *Educ. Res.* **2(2)**, 864–873.
- Radmehr, F. & Alamolhodaei, H. (2010). A Study on the Performance of Students' Mathematical Problem Solving Based On Cognitive Process of Revised Bloom Taxonomy. *J. Korea Soc. Math. Educ. Ser. D* **14(4)**, 381–403.
- Raghubar, K. P.; Barnes, M. A. & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences* **20(2)**, 110–122. ERIC EJ872587

- Richardson, F. C. & Suinn, R. M. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counseling Psychology* **19**(6), 551–554. ERIC EJ069707
- Saha, S. (2007). A study of Gender Attitude to Mathematics, Cognitive style and Achievement in mathematics. *Experiments in Education* **35**, 61–67.
- Saracho, O. N. (1998). Editor's introduction cognitive style research and its relationship to various disciplines. *International Journal of Educational Research* **29**, 169–172.
- Schweizer, K. & Moosbrugger, H. (2004). Attention and Working Memory as Predictors of Intelligence. *Intelligence* **32**, 329–347. ERIC EJ729984
- Singh, A. & Broota, A. (1992). Socio-personal variables and examination anxiety. *Journal of the Indian Academy of Applied Psychology* **18**, 73–78.
- Smith, G.; Wood, L.; Coupland, M. & Stephen, B. (1996). Constructing mathematical examination to assess a range of knowledge and skills. *Int. J. Math. Educ. Sci. Technol.* **21**(1), 65–77. ME **1996d**.02311
- Srivastava, P. (1997): *Cognitive style in educational perspective*. New Delhi, India: Anmol Publications Pvt. Ltd.
- Stuart, V. B. (2000). Math curse or math anxiety? *Teaching Children Mathematics* **6**(5), 330–338. ME **2000f**.03909 ERIC EJ602314
- Swanson, H. L. & Sachse-Lee, C. (2001). Mathematical problem solving and working memory in children with learning disabilities: Both executive and phonological processes are important. *Journal of Experimental Child Psychology* **79**(3), 294–321.
- Tannock, R. (2008). *Paying attention to inattention*. Paper presented at the Harvard Learning Differences Conference.
- Thomas, J. (2006). The effects on student's achievements and attitudes using integrated learning systems with co-operative pairs. *Journal Educational Technology Research and Development* **45**, 51–64.
- Trice, A. D. & Ogden, E. D. (1987). Correlates of mathematics anxiety in first-year elementary school teachers. *Educational Research Quarterly* **11**(3), 2–4. ERIC EJ374413
- Wigfield, A. & Meece, J. L. (1988). Math anxiety in elementary and secondary school students. *J. Educ. Psychol.* **80**(2), 210–216. ME **1989x**.00014 ERIC EJ388087
- Wilson, K. M. & Swanson, H. L. (2001). Are mathematics disabilities due to a domain-general or a domain-specific working memory deficit? *J. Learn. Disabil.* **34**(3), 237–248. ME **2002a**.00394 ERIC EJ626462
- Witkin, H. A.; Moore, C. A.; Goodenough, D. R. & Cox, P. W. (1977). Field-dependent and field-independent cognitive styles and their educational implications. *Review of Educational Research* **47**(1), 1–64. ERIC EJ161385
- Witkin, H. A. & Goodenough, D. R. (1981). *Cognitive styles: Essence and origins*. NY: International University Press.