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A Study on K5 students' mathematical problem solving based on Revised Bloom Taxonomy and psychological factors contribute to it

Diana Fardin and Farzad Radmehr
Ferdowsi University of Mashhad (Iran)

In this study, Revised Bloom's Taxonomy (RBT) was used as a touchstone for obtaining a profile of K5 students' mathematical problem solving in different cognitive process and levels of knowledge. In addition, the relationship between students' mathematical problem solving and psychological factors (i.e. Mathematics Anxiety, Mathematics Attitude, Mathematics Attention, Working Memory Capacity and Cognitive Style) has been discussed through the lens of RBT. A total 212 K5 girls (aged 11-12 years old) were tested on (1) K5 Mathematics questions based on RBT, (2) Digit Span Backwards Test (DBT), (3) Cognitive style (FD/FI) test, (4) Mathematics Anxiety Rating Scale, (5) Modified Fennema-Sherman Attitude Scales, (6) Mathematics Attention Test. Data of this research was analyzed by MANOVA repeated measure, General Linear models and graphs error bars from SPSS (Statistical Package for the Social Sciences) software. Obtained results indicate that students' have serious difficulties in solving Metacognitive knowledge problems and those concern to complex cognitive process. Moreover, psychological factors in question could predict Mathematical problem solving in different cognitive process and levels of knowledge. Overall, these findings could help to provide some practical implications for adapting problem solving skills and effective teaching/learning.
Keywords: Revised Bloom Taxonomy, Mathematical Performance, Psychological factors, Mathematics attitude, Mathematics anxiety.

Un estudio sobre el problema matemático de los estudiantes de K5' basado en la solución de Revisado Bloom Taxonomía y factores psicológicos contribuyen a ella. En este estudio, Taxonomía revisada de Bloom (TRB) fue utilizado como una piedra de toque para la obtención de un perfil del problema matemático de los estudiantes de K5' de problemas en diferentes procesos cognitivos y niveles de conocimiento. Además, la relación entre el problema matemático de los estudiantes de problemas y factores psicológicos (por ejemplo ansiedad Matemáticas, Matemáticas Actitud, Matemáticas Atención, capacidad de memoria de trabajo y el estilo cognitivo) se ha discutido a través del lente de la TRB. Un total de 212 niñas K5 (entre 11-12 años de edad) fueron probados en (1) preguntas K5 Matemáticas basado en la RBT, (2), el estilo cognitivo (FD/FI) Prueba Digit Span Prueba revés (DBT) (3), (4) Matemáticas Anxiety Rating Scale, (5) Modificado Fennema-Sherman Attitude Scales, (6) Prueba de Matemáticas de Atención. Los datos de esta investigación se analizó mediante MANOVA repite medida, modelos lineales generales y las barras de error gráficos de SPSS (Statistical Package for Social Sciences) de software. Los resultados obtenidos indican que los estudiantes tienen serias dificultades para resolver problemas de conocimiento metacognitivas y las preocupaciones de proceso cognitivo complejo. Por otra parte, los factores psicológicos en cuestión podrían predecir la resolución de problemas matemáticos en diferentes procesos cognitivos y niveles de conocimiento. En general, estos resultados podrían ayudar a proporcionar algunas implicaciones prácticas para la adaptación de las habilidades de resolución de problemas y la enseñanza/ aprendizaje efectivo.
Palabras clave: Revisado Bloom Taxonomía, rendimiento matemático, factores psicológicos, actitud Matemáticas, Matemáticas ansiedad.

Correspondence: Diana Fardin. School of Mathematical Sciences. Ferdowsi University of Mashhad. (Iran). E-mail: dfardin1352@yahoo.com

In the past decades, a greater emphasis has been placed on students' mathematical problem solving as reflected in standards for school mathematics (e.g., National Council of Teachers of Mathematics (NCTM), 1989, 2000). NCTM (1989) asserted that problem solving "should be the central focus of the mathematics curriculum" (NCTM, 1989, p. 23) and Polya (1949) and others (e.g., Branca, 1980) maintain that problem solving is the goal of mathematics learning. More recently, the NCTM reiterated its call for problem solving to form an integral part of the mathematics curriculum (NCTM, 2003). Regarding assessing students mathematical 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 in all of provinces 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 to the importance of math problem solving, the present study was carried to study students' mathematical problem solving based on cognitive process and knowledge dimension of Revised Bloom taxonomy (RBT). In addition, some psychological factors (Cognitive style, Working Memory capacity, mathematics attitude, mathematics anxiety and mathematics attention) have been considered and their effects on students mathematical problem solving have been investigated based on RBT. It seems to be more beneficial to describe the historical background of these variables and Revised Bloom Taxonomy before introducing research framework.

Revised Bloom Taxonomy

In the application of the Bloom's taxonomy since its publication in 1956, several weaknesses and practical limitations have been revealed. Besides, psychological and educational research has witnessed the introduction of several theories and approaches to learning which make students more knowledgeable of and responsible for their own learning, cognition, and thinking. Hence, a group of researchers revised the Original taxonomy in order to overcome its weaknesses and to incorporate the recent developments (Amer, 2006).

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 (Krietzer *et al.*, 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 and Krathwohl (2001) made some apparently minor but actually significant modifications that 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 improve reflection of the nature of the thinking defined in each category.

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 Remembering, Understanding, Applying, Analyzing, Evaluating and Creating. Each level of both dimensions of the table is subdivided.

Table 1. The Two Dimensional Taxonomy Table

Knowledge Dimension	The Cognitive Process Dimension					
	1. Remembering	2. Understanding	3. Applying	4. Analyzing	5. Evaluating	6. Creating
Factual knowledge						
Conceptual knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

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 and Miranda, 2002, p. 249).

Regarding to mathematical problem solving, Radmehr and Alamolhodaei (2010) for k11 students found that in each category of knowledge dimension (i.e., factual, conceptual, procedural, metacognitive) students' performed better in remembering mathematics objective than other cognitive process. After that, they performed better in applying mathematics objective and then understanding. However, there were no significant differences between problem solving in analyzing and evaluating mathematics objectives. Finally, their worst performance happened in creating mathematics objectives. They discovered that students' mathematical performances were decreased regularly. Students’ mathematical performance was better in applying mathematics questions than understanding mathematics questions since students can solve many mathematics problems without understanding the concepts. They just apply the algorithms that suitable for the questions. Researchers seen that many students can solve questions about limit and derivative without knowing the concept of them.

Mathematics Attitude

Mathematicians and mathematics educators have always experienced in their own practice the deep interplay between cognition and emotions, and the role it has on mathematical behavior. Scholars and teachers believe that mathematical activity is marked out by a strong interaction between cognitive and emotional aspects, attaching to the latter a driving role in the creative phase of mathematics (Martino & Zan, 2011). Mathematics is the one that triggers the strongest negative emotions, which may become established and even end up in an attitude of refusal towards the subject, or may block thinking processes (Buxton, 1981). As regards the definition of mathematics attitude, Martino & Zan (2011) described it as a “characterization of attitude towards mathematics grounded in students’ experiences, investigating how students express their own relationship with mathematics”.

Many researchers report that positive mathematical beliefs, attitudes, and feelings will lead to increased mathematical achievement (Grootenboer, 2003a; Hassi &

Laursen, 2009; Wilkins & Ma, 2003). Attitudes towards mathematics appear to be very important in relation to differences in achievement as well as in participation in mathematics courses. According to literature, attitude can predict achievement and that achievement, in turn, can predict attitude (Fardin *et al.*, 2011; Meelissen & Luyten, 2008). Negative attitudes and emotions, together with inadequate self regulatory behaviors, are often connected with students' preventive beliefs and perceptions in mathematics learning situations (DeBellis & Goldin, 2006; Malmivuori, 2001; McLeod, 1992).

Mathematics Anxiety

The negative effects of mathematics anxiety on students' achievements have interested researchers for a number of years (e.g., Alamolhodaei, 2009; Ashcraft & Kirk, 2001; Kramarski *et al.*, 2010; Sherman & Wither, 2003). According to Richardson and Suinn (1972), mathematics anxiety is defined as "feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (p. 551).

Considering that childhood is a period of rapid change, ages 9-11 seem to be a critical stage for the development of attitudes and emotional reactions towards mathematics (McLeod, 1993). Generally, meta-analysis studies have indicated that once formed, negative attitudes and anxiety are difficult to change and may persist into adult life with far-reaching consequences (Gierl & Bisanz, 1994; Kramarski *et al.*, 2010; Ma, 1999). Some of these consequences include a voidance of mathematics, distress, and interference with conceptual thinking and memory processes (Kramarski *et al.*, 2010). In addition, Researchers have suggested that one of the possible causes of mathematics anxiety in children may be teaching methods which emphasize the memorization of basic skills rather than process-oriented methods geared towards problem solving, understanding and reasoning (Kramarski *et al.*, 2010; Stodolsky, 1985).

Mathematics Attention

Mathematics is a way of thinking and requires a great deal of attention, particularly when multiple steps are involved in the problem solving process. 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 (Amani, Alamolhodaei & Radmehr, 2011).

At the heart of math attention is the issue of how many tasks can be done at same time to reach a solution. According to Ellis and 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 quiet limited.

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 capacity (WMC) is a causative (Tannock, 2008).

According to Alloway *et al.* (2009) the majority of research on working memory (WM) and learning has demonstrated a relation among these two parts of WM, i.e, verbal and visuo spatial components. It is possible that poor working memory skills are the cause of the learning difficulties encountered by children with dyslexia and attention deficit hyperactivity disorder (ADHD). Based upon Alloway *et al.* (2009) findings, teachers typically judged the children with low WMC were highly inattentive and having poor attention spam and high levels of distractibility. These students often made carless mistakes, particularly, in solving problems in every day classroom activities and making high risk of poor academic progress, in particular, in mathematics.

Finally, According to Alamolhodaei, Farsad and Radmehr (2011) math attention has the highest path coefficient to mathematical performance between math attitude, math attention, field dependency and metacognitive ability. During math instruction, students who have attention difficulties often miss some important parts of the content.

Working memory capacity

The working memory is that part of the brain where we hold information to work upon, organize, and shape it before storing in long-term memory for further use (Johnstone, 1984; Ribaupierre and Hitch, 1994). In addition, researchers described it as a mental workspace, that involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks (e.g., mathematical processing) (Baddeley, 1986; Miyake & Shah, 1999; Raghubar *et al.*, 2010). In fact, Baddeley’s (1990) model of WM has been particularly useful in explaining a variety of thinking phenomena (Niaz and Logie, 1993).

Mathematical competence entails a variety of complex skills that encompass somewhat different conceptual content and procedures (e.g., arithmetic, algebra, and geometry); problem solving in these domains often involves the holding of partial information and the processing of new information to arrive at a solution, which ought to require working memory resources (Raghubar *et al.*, 2010). There are some considerable evidences suggesting that WM may be important for mathematics learning and problem solving. For instance, Adams and Hitch (1998) suggested that mental arithmetic performance relies on the recourses of WM. Significant associations have been found between the phonological loop and mental arithmetic performance (Adams and Hitch, 1998; Holmes and Adams, 2006; Javris and Gathercole, 2003). Moreover researchers, (i.e., Alamolhodaei, 2009; Alamolhodaei & Farsad, 2009,...) have found that the students with high WMC, are more capable of solving mathematics problems compared to those with low WMC.

Cognitive style

Field dependence/independence (FDI) or disembedding ability cognitive style represents the ability of individual to disembed information (cognitive restructuring) in a variety of complex and potentially misleading in structural context (Collings, 1985; Niaz, 1996; Witkin *et al.*, 1977). 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 (Alamolhodaei, 2009; Amani *et al.*, 2011; Saracho, 1998; Witkin and Goodenough, 1981).

According to Witkin and 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. Cognitive style has been reported to be one of the significant factors that may impact students' achievement on various school subjects (see, Murphy, Casey, Day & Young, 1997; Cakan, 2000). Several researchers have demonstrated the importance of field dependency in science education and mathematical problem solving, in particular word problems (Alamolhodaei, 2002, 2009; Johnstone and Al-Naeme, 1991, 1995; Witkin and Goodenough, 1981). 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.

Research Framework

When researchers replace their mathematics questions to the questions that consist of RBT, they may find more insight of the level of students understanding. This knowledge could help them to be familiar with mathematics education problems and students difficulties (Radmehr & Alamolhodaei, 2010). Therefore, these types of questions for this study have been chosen. The focus of this research was to provide a profile of K5 students' mathematical problem solving in the different cognitive process and knowledge dimension of the RBT. Thus, the first main question addressed here is: *Is there any difference between students' mathematical problem solving in different cognitive process and knowledge dimension of RBT?*

Moreover, since in recent studies the effect of psychological factors on mathematical problem solving were considered as a whole and students' performance haven't analyzed through the lens of RBT, in this study an exploratory position has been taken to find the relationship between each of these psychological factors and students' problem solving in different cognitive process and knowledge dimension of RBT. Therefore, the second main question is, what are the effects of the psychological factors on students' mathematical problem solving in different cognitive process and knowledge dimension of RBT? In an attempt to answer these questions the following objectives were sought. The first objective of the study was to investigate whether there was any difference between students' mathematical performance in each cognitive process (*i.e*., remembering, understanding, applying, analyzing, evaluating, and creating) according to knowledge dimension (*i.e*., factual, conceptual, procedural, and metacognitive) of RBT. The second objective of the study was to discover whether there was any difference between students' mathematical performance in each knowledge categories (*i.e*., factual, conceptual, procedural, and metacognitive) according to cognitive processes (*i.e*., remembering, understanding, applying, analyzing, evaluating, and creating) of RBT. The third 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. The fourth 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 RBT and each of these psychological factors**.**

METHOD

Participants

A total 212 K5 girls (aged 11-12 years old) were selected from two schools of Mashhad (Khorasan Razavi Province) using random multistage stratified sampling design. This study was conducted during regular school hours in intact classes in 2011-2012 school years.

Instruments and Procedures

The research instruments were:

(1) K5 Mathematics questions based on RBT, (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

This study is a part of 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, Algebra 1 and Analyze 1 for mathematics students). This paper introduces the results obtained for K5 students. 120 mathematics questions from K5 math syllabus were designed similar to Radmehr & Alamolhodaei (2010) based on RBT definitions for each cells. Each 5 questions were examined one of the cells in RBT. RBT has 24 cells so 120 questions are needed to cover all of them. 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 part contains 40 questions:

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

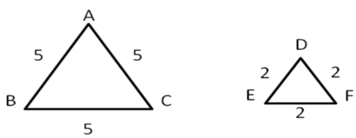
Part two examined applying and analyzing cells (including: applying factual, conceptual, procedural and metacognitive knowledge, analyzing factual, conceptual, procedural and metacognitive knowledge).

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

Here are some typical questions of this exam.

Sample Question 1. *For adding two fractions with different denominator, first what should we do?* Students for answering this question should remember the method that they can add two fractions with different dominator. According to the knowledge dimension of the RBT, procedural knowledge defined as How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods. So this question place in the cell concerning to *remembering procedural knowledge*.

Sample Question 2. *Are the angles ABC and DEF in these triangles are equivalent?*



First of all, students for answering to this question should remember the properties of equilateral triangle which in this type of triangle all the angles are equal

and have 60 degree. But if students haven’t understand this conceptual knowledge (whether side of an equilateral triangle is different from another one, their angles share the same degree which is equal to 60) maybe they make a mistake and say that ABC is greater than EDF because the length of AC is greater than DF. Conceptual knowledge in RBT contains the following knowledge: knowledge of classifications and categories, knowledge of principles and generalizations and knowledge of theories, models, and structures (Krathwohl *et al.*, 2002).
It is obvious that this proposition is part of conceptual knowledge and based on cognitive process of RBT interpreting is part of understanding so this question placed in *understanding conceptual knowledge* cell.

Sample Question 3. *What are the differences and similarities between Rhombus and square?* According to cognitive process of RBT, differentiating is part of analyzing and for answering this question students’ need to differentiating the property of Rhombus and square so this question placed in analyze group and these two concept (Rhombus and square) for K5 students is part of conceptual knowledge so this question placed in the cell concerning to *Analyzing conceptual knowledge.*

Sample Question 4. Which of these two fractions is nearer to 2? $^{82}/_{46,}$ $^{88}/_{49}$

$^{82}/_{46,}$ $^{88}/_{49}$ are part of factual knowledge and students for answering this question should checking which one of this fractions are nearer to 2 so the students’ should evaluating factual knowledge to answer to this question. Therefore this question placed in *evaluating factual knowledge* cell.

Sample Question 5. Explain two methods for determining that if an integer is divisible to 8 or not? Researchers should note that creating questions that used in this study, chosen from objectives that doesn’t exist directly in the K5 mathematics book so students need to think and use their mathematics knowledge to create new objectives. In addition, we know that Strategic knowledge is a part of metacognitive knowledge (according to knowledge dimension of RBT) so this question is a *creating metacognitive knowledge question.*

Digit Span Backwards Test (DBT)

For measuring students’ WMC, DBT has been showed to be the most suitable test (Alamolhodaei, 2009; Case, 1974; Maloney *et al.*, 2010; Pezeshki *et al.*, 2011; Raghubar *et al.*, 2010). 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. The test continued with the addition of one item every second trial until participants made errors on two trials in a row. The participant’s score was the highest number of digits on which they made no errors.

Mathematics Anxiety Rating Scale (MARS)

The level of anxiety was determined by the score attained on the Math Anxiety Rating Scale (MARS). 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-l). Cronbach's alpha, the degree of internal consistency of mathematics attention test items for this study was estimated to be .90.

Cognitive style (FD/FI) Test

The GEFT (Group Embedded Figures Test) created by Oltman *et al.* (1971). The GEFT examines subjects' ability to identify a simple figure which is embedded in a more complex pattern. There are 8 simple and 20 complex figures, which make up the GEFT. The estimate of reliability of the GEFT is .82 (Witkin, Oltman, Raskin & Karp, 1971). Students' cognitive styles were determined according to a criterion used by (Alamolhodaei, 1996, 2009; Amani, Alamolhodaei & Radmehr, 2011; Case 1974; Mousavi *et al.*, 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 student's attitude(s) towards mathematics. Since 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 levels of mathematics attention were determined by attention test which has been developed in the school of Mathematical Sciences, Ferdowsi University of Mashhad (Amani *et al.*, 2011). 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.

Data Analysis

Data of the present study were analyzed by inferential statistics. Hypotheses of the study were analyzed by MANOVA repeated measure, Pearson correlation and Generalized linear model (GLM) with the Statistical Package for the Social Sciences (SPSS).

RESULTS

Analyzing Students' mathematical problem solving based on cognitive process of RBT

Using MANOVA repeated measures we obtain a p-value less than 0.001 regarding Hotelling's statistic so the hypothesis of equality of mean's students' mathematical problem solving in these four rows of RBT (1- remembering, understanding, applying, analyzing, evaluating and creating factual knowledge, 2- remembering, understanding, applying, analyzing, evaluating, and creating conceptual knowledge, 3- remembering, understanding, applying, analyzing, evaluating and creating procedural knowledge, 4- remembering, understanding, applying, analyzing, evaluating and creating metacognitive knowledge) were rejected according to table 2. Graphs of error bar have shown the difference between students' mathematical performance in factual, conceptual, procedural and metacognitive knowledge according to cognitive process of RBT.

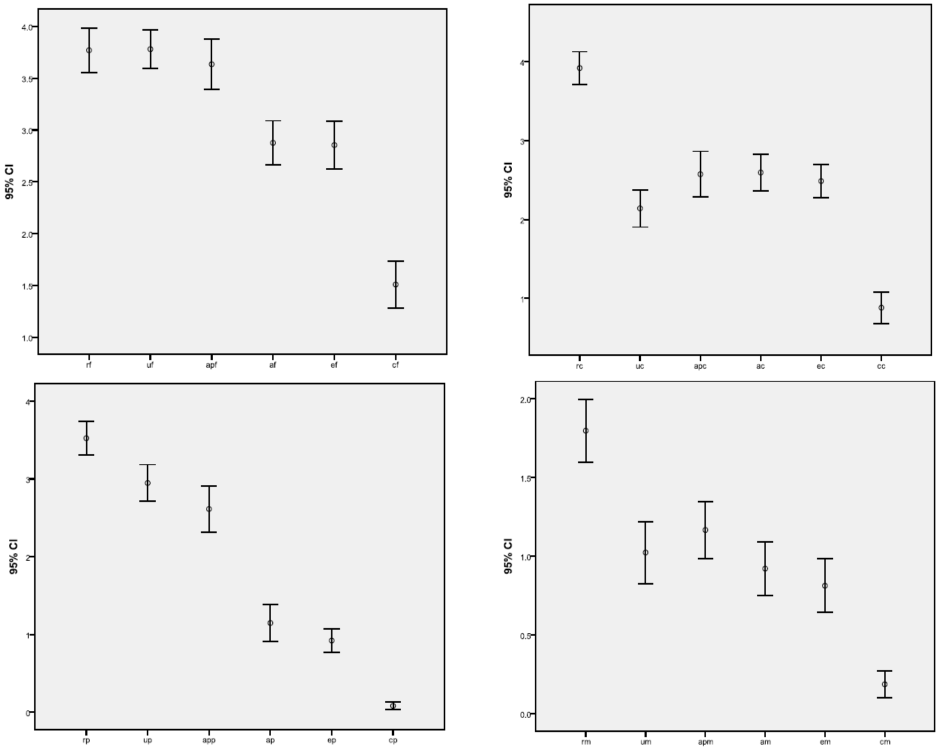
Table 2. P-values of each knowledge dimension based on MANOVA test

Title	P-value
Factual knowledge	Less than 0.001
Conceptual knowledge	Less than 0.001
Procedural knowledge	Less than 0.001
Metacognitive knowledge	Less than 0.001

According to figure 1, there is a significant difference between students' mathematical problem solving concern to remembering, understanding and applying math factual knowledge in contrast to analyzing, evaluating and creating mathematical factual knowledge questions. Indeed, there is a large gap between students' mathematical problem solving concern to creating factual knowledge and other parts.

Based on second group of graphs of figure 1, it can be seen that students were more successful in answering remembering conceptual knowledge questions than other parts. And there wasn't any significant difference between students' mathematical problem solving concern to applying, analyzing and evaluating mathematical conceptual knowledge questions. Similar to previous part, students' mathematical performance concern to creating conceptual knowledge questions was weaker than other parts.

Figure 1. Students' mathematical problem solving based on cognitive process of RBT



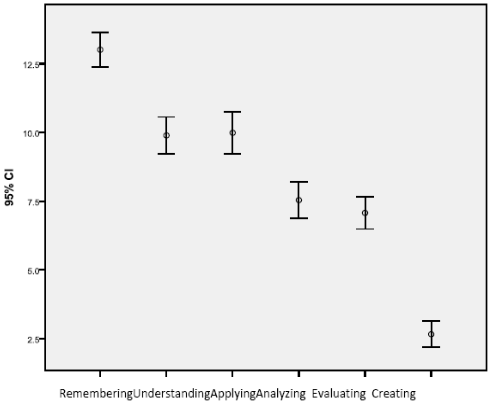
Note: R=Remember, U=Understand, Ap=Apply, A=Analyze, E=Evaluate, C=Create, F=Factual Knowledge, C=Conceptual Knowledge, P=Procedural Knowledge, M=Metacognitive Knowledge.

Third group of graphs of figure 1, shown that students were more successful in answering remembering mathematical procedural knowledge questions than other parts. In addition, we should note that there isn't any significant difference between students' answering to understanding and applying procedural knowledge questions. Students' performance in higher level of thinking (i.e., analyze, evaluate and create) was significantly lower than remembering, understanding and applying math procedural knowledge questions. Finally we should note that students have serious difficulty in answering create math procedural knowledge questions because their means concern to this type of questions was approximately 0.1.

Last group of graphs of figure 1, shown that students were more successful in answering remembering mathematical metacognitive knowledge questions than other sections. In addition, it shown that they hadn't significant difference in term of answering to mathematical questions concern to understanding, applying, analyzing and evaluating metacognitive knowledge questions. Moreover, there is a large gap between students' mathematical problem solving concern to creating metacognitive knowledge than other parts.

According to Figure.2, students' mathematical problem solving were decreased from remembering mathematical objective through creating math objective. As can be seen from this Figure, there isn't any significant difference between students' mathematical problem solving concern to understanding and applying questions. Moreover, there isn't any significant difference between students' performance in term of analyzing and evaluating math objectives. Finally, they had serious difficulty in answering to questions concern to creating math objectives.

Figure 2. Comparing mathematical performance in cognitive process dimension



Analyzing Students' mathematical problem solving based on Knowledge dimension of RBT

Using MANOVA repeated measures we obtain a p-value less than 0.001 regarding Hotelling's statistic so the hypothesis of equality of mean's students' mathematical problem solving in these six columns of RBT (1- Remembering factual, conceptual, procedural and metacognitive knowledge, 2- Understanding factual, conceptual, procedural and metacognitive knowledge, 3- Applying factual, conceptual, procedural and metacognitive knowledge, 4- Analyzing, factual, conceptual, procedural and metacognitive knowledge, 5- Evaluating factual, conceptual, procedural and metacognitive knowledge, 6- Creating factual, conceptual, procedural and metacognitive knowledge) were rejected according to table 3. Graphs of error bar have shown differences between students' mathematical problem solving in remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives according to knowledge dimension of RBT.

Table 3. P-values of each cognitive process based on MANOVA test

Title	P-value
Remembering math objectives	Less than 0.001
Understanding math objectives	Less than 0.001
Applying math objectives	Less than 0.001
Analyzing math objectives	Less than 0.001
Evaluating math objectives	Less than 0.001
Creating math objectives	Less than 0.001

According to first Graphs of figure 3, there isn't any significant difference between students' mathematical problem solving in questions concern to remembering factual, conceptual and procedural knowledge but there is a large gap between students' mathematical problem solving in these three types of questions and remembering metacognitive knowledge questions.

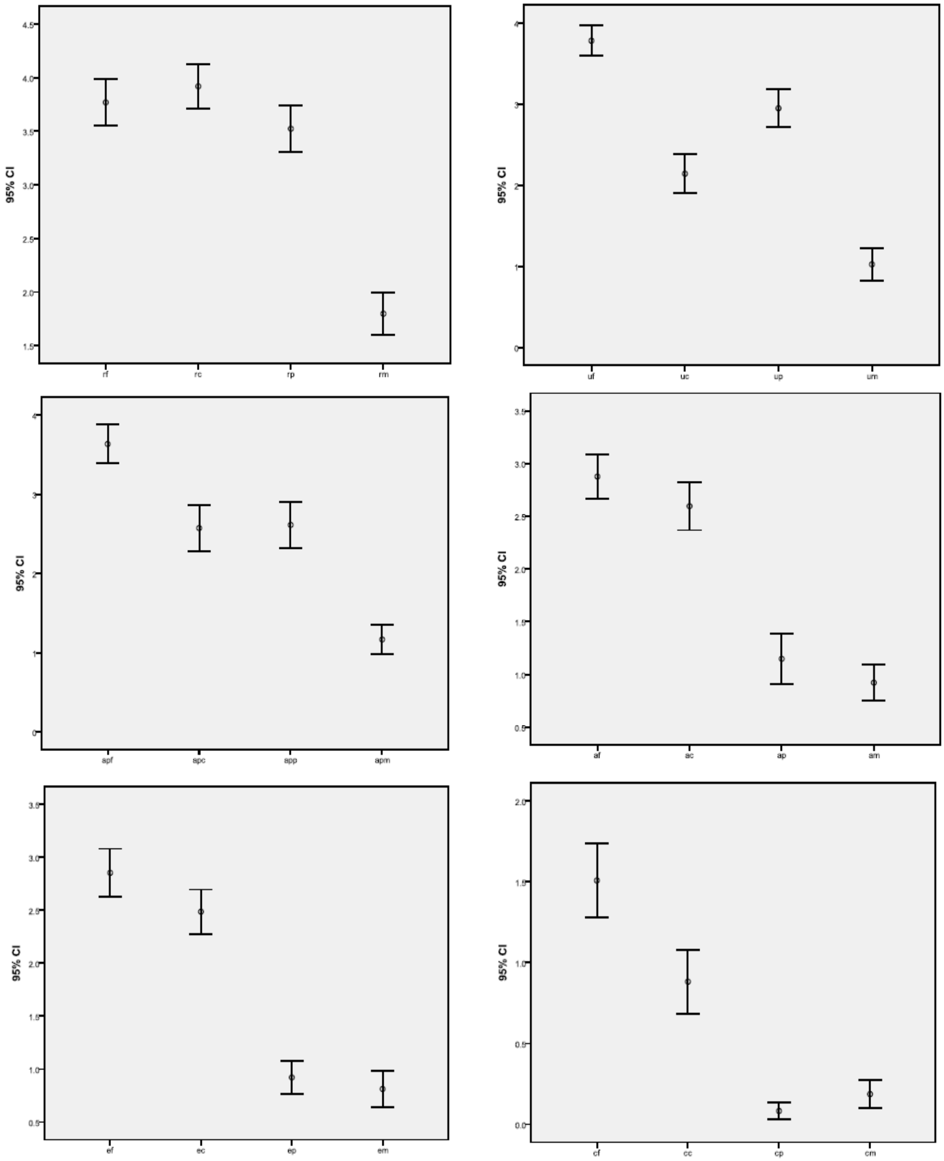
Second graphs of figure 3 shown that there are significant differences between students' mathematical problem solving concern to understanding mathematical objectives in different levels of knowledge dimension of RBT. They performed better in answering to questions concern to understanding factual knowledge and their lower Mathematical performance was in questions concern to understanding metacognitive knowledge.

According to third graph of figure 3, students mathematical problem solving was better in applying factual knowledge questions and there isn't any significant difference between students' answering to questions concern to applying conceptual knowledge and procedural knowledge. Indeed, students' mathematical problem solving in applying metacognitive knowledge questions was lower than other parts.

From fourth graph of figure 3 can be seen that Students are more successful in answering analyzing factual and conceptual knowledge questions than analyzing procedural and metacognitive knowledge questions. Besides, there isn't significant difference between answering to analyzing procedural and metacognitive knowledge questions. Nevertheless, students' performance concern to analyzing metacognitive questions was lower than other parts.

Fifth graphs of figure 3 shown that there is a large gap between students mathematical problem solving concern to evaluating factual and conceptual knowledge in contrast to evaluating procedural and metacognitive knowledge. Like previous groups, students better performed in factual knowledge and lower performance was belonging to metacognitive knowledge. Last graphs of figure 3 shown that students have serious weaknesses in solving create procedural and metacognitive questions. Moreover, students' better performance was shown in creating factual and conceptual knowledge questions, respectively.

Figure 3. Students mathematical problem solving based on Knowledge dimension of RBT

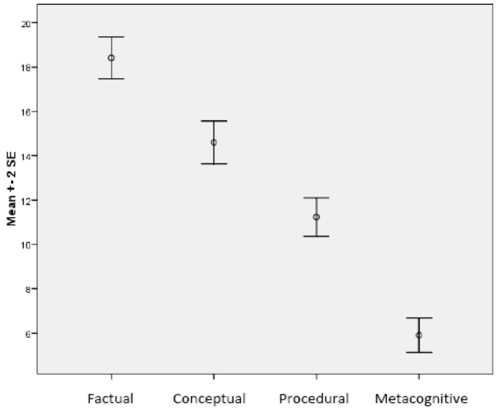


Note: R=Remember, U=Understand, Ap=Apply, A=Analyze, E=Evaluate, C=Create, F=Factual Knowledge, C=Conceptual Knowledge, P=Procedural Knowledge, M=Metacognitive Knowledge.

Based on figure 4, students' mathematical problem solving was decreased from mathematical factual knowledge through mathematical metacognitive knowledge.

As can be seen from this figure, there is a significant difference between students' mathematical problem solving in these levels of knowledge.

Figure 4. Comparing mathematical performance in knowledge dimension



Effects of psychological factors on students mathematical problem solving based on cognitive process of RBT

Pearson's correlations between students' mathematical problem solving in different cognitive process (i.e., Remembering, Understanding, Applying, Analyzing, Evaluating and Creating math objective) and psychological factors (i.e., WMC, GEFT score, Mathematics Attitude, Mathematics Anxiety, Mathematics Attention) were conducted. Table 4 showed significant positive correlation at the 0.01 level for GEFT score, WMC, mathematics attitude and students' mathematical problem solving in different cognitive process.

Table 4. Students' mathematical problem solving based on cognitive process of RBT and psychological factors

	Remembering math objective	Understanding math objective	Applying math objective	Analyzing math objective	Evaluating math objective	Creating math objective
Working Memory Capacity	.482***	.406***	.346***	.452***	.414***	.465***
Mathematics Attitude	.454***	.451***	.305***	.376***	.394***	.483***
Mathematics Anxiety	-.343***	-.298***	-.200**	-.206**	-.232**	-.186*
Mathematics Attention	.243**	.098	.021	.198**	.120	.216**
GEFT score	.410***	.416***	.434***	.350***	.318***	.435***

Note: ***Correlation is significant at the 0.01 level (2-tailed). **Correlation is significant at the 0.05 level (2-tailed). *****Correlation is significant at the 0.1 level (2-tailed).

For mathematics anxiety, significant negative correlation obtained according to table 4 at .01 levels for remembering and understanding mathematical objectives.

Concerning to applying, analyzing and evaluating math objective significant negative correlation found at .05 levels. And for creating math objective the correlation was significant at 0.1 levels. Concerning to mathematics attention, significant positive correlation was obtained between this factor and students' mathematical problem solving concern to remembering, analyzing and creating math objectives at 0.05 levels.

In addition, GLM was conducted to determine the effects of these psychological factors on students' mathematical problem solving based on RBT more precisely. GLM is a flexible generalization of ordinary linear regression. The GLM generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value.

According to GLM, these psychological factors can predict students' mathematical problem solving in different cognitive process at p-value less than 0.001 for WMC, GEFT score, Mathematics attitude, at .0.025 for mathematic anxiety and at 0.019 for mathematics attention.

WMC explains 0.225, 0.157, 0.112, 0.197, 0.164 and 0.206 of the variance (R squared) of students' mathematical problem solving concern to remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives respectively which are significant as indicated by table 5.

Mathematics attitude significantly describes 0.206, 0.204, 0.093, 0.142, 0.155 and 0.234 of the variance (R squared) of students' mathematical problem solving concern to remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives respectively according to table 5.

Mathematic anxiety explains 0.118, 0.089, 0.040, 0.042, 0.054 and 0.035 of the variance (R squared) of students' mathematical problem solving concern to remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives respectively.

Table 5. GLM on students' mathematical problem solving based on cognitive process of RBT and psychological factors

	Hotelling's Trace	Remembering math objective		Understanding math objective		Applying math objective		Analyzing math objective		Evaluating math objective		Creating math objective	
	P-value	P-value	R-Square	P-value	R-Square	P-value	R-Square	P-value	R-Square	P-value	R-Square	P-value	R-Square
Working Memory Capacity	0.000	0.000	.225	0.000	.157	0.000	.112	0.000	.197	0.000	.164	0.000	.206
Mathematics Attitude	0.000	0.000	.206	0.000	.204	0.003	.093	0.002	.142	0.005	.155	0.000	.234
Mathematics Anxiety	0.025	0.000	.118	0.002	.089	0.045	.040	0.039	.042	0.020	.054	0.063	.035
Mathematics Attention	0.019	0.011	.059	0.313	.010	0.828	0.001	0.039	.039	0.214	.014	0.024	.046
GEFT score	0.000	0.000	.142	0.000	.136	0.000	.174	0.002	.085	0.005	.072	0.000	.144

Mathematics attention as a dependent variable explains .059, 0.010, 0.001, 0.39, 0.014 and 0.046 of the variance (R squared) of students' mathematical problem solving concern to remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives respectively which are significant for remembering, analyzing and creating math objectives.

Concern to GEFT score, it describes 0.142, 0.136, 0.174, 0.085, 0.072 and 0.144 of the variance (R squared) of students' mathematical problem solving concern to remembering, understanding, applying, analyzing, evaluating and creating mathematical objectives respectively which are significant as shown by table 5.

Effects of psychological factors on students mathematical problem solving based on knowledge dimension of RBT

Also for knowledge dimension Pearson's correlations between students' mathematical problem solving in different levels of RBT (i.e., Mathematical factual, conceptual, procedural and metacognitive knowledge) and psychological factors (i.e., WMC, GEFT score, Mathematics Attitude, Mathematics Anxiety, Mathematics Attention) were conducted. Table 6 showed significant positive correlation at the 0.01 level for GEFT score, WMC, mathematics attitude and students' mathematical problem solving in different level of knowledge dimension. For mathematics anxiety, significant negative correlation obtained at .01 levels. Concerning to mathematics attention, significant positive correlation was found between this factor and students' mathematical problem solving in factual knowledge at 0.01 levels and at 0.1 levels for conceptual knowledge while for procedural and metacognitive knowledge, no significant relationship was found.

Table 6. students' mathematical problem solving based on knowledge dimension of RBT and psychological factors

	Math factual Knowledge	Math conceptual Knowledge	Math procedural Knowledge	Math metacognitive knowledge
Working Memory Capacity	.474***	.488***	.356***	.492***
Mathematics Attitude	.392***	.421***	.441***	.499***
Mathematics Anxiety	-.288***	-.238**	-.249**	-.288***
Mathematics Attention	.301***	.161*	.049	.073
GEFT score	.439***	.382***	.378***	.498***

Note: ***Correlation is significant at the 0.01 level (2-tailed). **Correlation is significant at the 0.05 level (2-tailed). ***** Correlation is significant at the 0.1 level (2-tailed).

Also for knowledge dimension, GLM was conducted. These psychological factors can predict students' mathematical problem solving in different level of knowledge at p-value less than 0.001 for WMC, GEFT score, Mathematics attitude, at 0.037 for mathematic anxiety and at 0.001 for mathematics attention.

WMC explains 0.224, 0.238, 0.127 and 0.242 of the variance (R squared) of students' mathematical problem solving concern to mathematical factual, conceptual, procedural and metacognitive knowledge respectively which are significant as indicated by table 7.

Mathematics attitude describes 0.154, 0.177, 0.195 and 0.249 of the variance (R squared) of students' mathematical problem solving concern to mathematical factual, conceptual, procedural and metacognitive knowledge respectively which are significant as shown by table 7.

Mathematics anxiety as a dependent variable explains 0.083, 0.057, 0.062 and 0.083 of the variance (R squared) of students' mathematical problem solving concern to mathematical factual, conceptual, procedural and metacognitive knowledge respectively.

Concern to GEFT score, It describes 0.145, 0.096, 0.129 and 0.223 of the variance (R squared) of students' mathematical problem solving concern to mathematical factual, conceptual, procedural and metacognitive knowledge respectively.

Table 7. GLM on students' mathematical problem solving based on knowledge dimension of RBT and psychological factors

	Hotelling's Trace	Math factual Knowledge		Math conceptual knowledge		Math procedural knowledge		Math metacognitive knowledge	
	P-value	P-value	R-Square	P-value	R-Square	P-value	R-Square	P-value	R-Square
Working Memory Capacity	0.000	0.000	.224	0.000	.238	0.000	.127	0.000	.242
Mathematics Attitude	0.000	0.000	.154	0.000	.177	0.000	.195	0.000	.249
Mathematics Anxiety	0.037	0.004	.083	0.017	.057	0.012	.062	0.003	.083
Mathematics Attention	0.001	0.001	.090	0.094	.026	0.611	0.002	0.448	.005
GEFT score	0.000	0.000	.145	0.001	.096	0.000	.129	0.000	.223

Finally, mathematics attention explains .090, 0.026, 0.002 and 0.005 of the variance (R squared) of students' mathematical problem solving relate to mathematical factual, conceptual, procedural and metacognitive knowledge respectively which are significant for factual knowledge (P-value=0.001) and conceptual knowledge (P-value=0.094) as shown by table 7.

DISCUSSIONS AND CONCLUSION

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 (NCTM, 1989; NCTM, 1991). As mentioned earlier, when researchers replace their mathematics questions to the questions that consist of RBT, they may find more insight of the levels of students' understanding and how they solve mathematical problems.

Therefore, these types of questions for this study have been chosen. The focus of this research was to provide a profile of K5 students' mathematical problem solving in the different cognitive process and knowledge dimension of the RBT. Moreover, since in recent studies the effect of psychological factors on mathematical problem solving were considered as a whole and students' performance haven't analyzed through the lens of RBT, in this study an exploratory position has been taken to find the relationship between each of these psychological factors and students' problem solving in different cognitive process and knowledge dimension of RBT.

According to results, in each category of knowledge dimension (i.e., factual, conceptual, procedural, metacognitive) students performed better in remembering mathematics objective than each five parts and after that they performed better in applying and understanding mathematical objectives. Moreover, it can be seen that students' have serious weaknesses in solving mathematical problems concern to creating tasks.

According to figure 2, students' mathematical performances were decreased regularly in these cognitive processes (i.e., Remembering, Understanding, Applying, Analyzing, Evaluating and Creating).

In addition, in each cognitive process, students performed better in factual knowledge in comparison to conceptual, procedural and metacognitive knowledge. Besides, according to figure 4, students' mathematical performances were decreased regularly in knowledge dimension. Moreover, results obtained indicate that students' have several weaknesses in solving mathematical problems concern to metacognitive knowledge. It was in line with Radmehr and Alamolhodaei (2010) that students have several weaknesses in complex cognitive processes such as analyzing, evaluating and creating. On the other hand, in regards of knowledge dimension it was supported by Radmehr & Alamolhodaei (2012), that students have serious problems in solving metacognitive knowledge questions. However, their results concerned to K11 and similar results in this study obtained for K5.

Therefore, questions based on RBT provide useful profile of students' mathematical problem solving in different cognitive process and knowledge dimension. Mathematics teachers should pay attention to these weaknesses and try to enhance students' mathematical performance in complex cognitive process. In addition, they should try to improve students' metacognitive knowledge since students' have several difficulties in solving these types of questions.

Concern to second part of this research, obtained results indicate that each of these psychological factors (i.e., Math anxiety, attitude, attention, WMC, cognitive style) significantly predicted mathematical problem solving while their effect varied based on the cognitive process and levels of knowledge (Table 5 & Table 7). According to previous studies in mathematics education, these psychological factors contributed to mathematical problem solving. However, 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 results of this study students' mathematical problem solving in different cognitive process and knowledge dimension was negatively correlated to mathematics anxiety. In addition, GLM analysis found Mathematics anxiety as a predictor of Mathematical performance in each cognitive process (P-value less than 0.05 for *Remembering, Understanding, Applying, Analyzing, Evaluating* and less than 0.1 for *Creating*) and levels of knowledge (P-value less than 0.05 in each of them). Findings of this study support previous claims that math anxiety could predict mathematical problem solving (e.g., Baloglu & Kocak, 2006; Alamolhodaei, 2009; Hembree, 1990; Pezeshki *et al.*, 2011). Moreover, the results of this study were shown that these negative relations lie around all of cognitive process and in different levels of knowledge. This could be the most remarkable finding of the present study.

Regarding Mathematics attitude, obtained results indicate that there is significant positive correlation between student' Mathematics attitudes and Mathematical problem solving in different cognitive process and levels of knowledge of RBT at .01 level. Besides, GLM revealed that Mathematics attitude is one of predictors of Mathematical performance at 0.01 level in each cognitive process and levels of knowledge. It was supported by the previous studies that there is a positive relation between mathematics attitude and mathematics problem solving (Fardin, Alamolhodaei & Radmehr, 2011; Ma & Kishor, 1997a; Meelissen & Luyten, 2008; Saha, 2007; Thomas, 2006). For math attention, the results of this study were the same as previous research of Alamolhodaei, Farsad & Radmehr (2011) that Mathematics attention is a predictor of mathematical problem solving. Moreover, this study shown that this relationship seems to be in *Remembering*, *Analyzing* and *Creating* mathematical objectives and in *Factual* and *Conceptual* knowledge.

Concern to WMC, students' mathematical problem solving in different cognitive process and knowledge dimension was positively correlated to WMC. In addition, GLM analysis introduced WMC as a predictor of Mathematical problems solving in each cognitive process and levels of knowledge at 0.01 levels. It was in line with previous researches in this field that students with higher WMC have better performance in mathematical problems than lower ones. (e.g., Alamolhodaei, 2009; Alloway, 2006; Mousavi *et al.*, 2012; Raghubar *et al.*, 2010).

Finally, regarding students' GEFT score, the results of this study support previous claims that GEFT score is a predictor factor of Mathematical problem solving (e.g., Alamolhodaei, 2002, 2009; Mousavi, Radmehr & Alamolhodaei, 2012). In addition, this study shown that GEFT score is a predictor of Mathematical performance in each levels of knowledge and cognitive process at 0.01 levels.

The findings of this study obtained more insight about *How psychological factors affects 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.

In addition, we should try to enhance their attitudes toward mathematics to improve their performance in mathematical problem solving in different cells of RBT. Students with low WMC and GEFT score should be helped by teachers to show roughly the same mathematical performance as students with high ones. Finally, teachers should use strategies that students got the maximum math attention so they can 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.

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