Exploring the relationship between Iranian students' Mathematical Literacy and Mathematical performance

Robabe Afkhami[1], Hassan Alamolhodaei [2], Farzad Radmehr[3]

[1.] School of Mathematical Sciences, Ferdowsi University of Mashhad, Iran r_afkhami@yahoo.com
[2.] School of Mathematical Sciences, Ferdowsi University of Mashhad, Iran Alamolhodaei@yahoo.com
[3.] School of Mathematical Sciences, Ferdowsi University of Mashhad, Iran f.radmehr65@gmail.com

Abstract: The main objective of this study is to investigate students' Mathematical Literacy(ML) in elementary, secondary and high school. The purpose of ML is students' ability to use mathematics to solve context related problems in real world .In the theoretical framework of ML in the international PISA study, mathematics is divided four categories space and shape, change and relationships, quantity and uncertainty. A sample of 90 students from elementary school (10-11years old), 118 students from secondary school (14-15 years old) and 70 students from high school (17-18 years old) were tested on mathematical literacy and the Witkin's cognitive style (Group Embedded Figure Test) test. The findings of this study showed that students in elementary school were more successful and literate than secondary and high school students. ML of secondary and high school students showed no significant difference. Also obtained results indicate that FI students in ML test were better than FD students. [Robabe Afkhami, Hassan Alamolhodaei, Farzad Radmehr. **Exploring the relationship between Iranian students' Mathematical Literacy and Mathematical performance.** Journal of American Science 2012;8(4):213-222]. (ISSN: 1545-1003). http://www.americanscience.org. 29

Keywords: Mathematical Literacy, Mathematical performance, Cognitive style

1. Introduction

Create modern interpretation of ML - the ability to apply mathematics in different situations – is a goal for many educational systems in the world. The term ML for the first time has been raised officially, in the Trends in International Mathematics and Science Study (TIMSS) in 1995.The main motivation for this study, the evidence showed that many children in the school graduates, don't access knowledge of math and science that is necessary for dealing with workplace issues. In addition, another most important reason is considered for the design and implementation of international studies in general and TIMSS advanced in particular was the relationship between ML and economic growth. The same term was used in Programme for International Student Assessment) PISA (. In the current OECD (Organization for Economic Co-operation and Development) Study PISA, relations between the real world and mathematics are particularly topical. What is being tested in PISA is 'Mathematical Literacy', that is: "an individual's capacity to identify and understand the role that mathematics plays in the world, to make well-founded judgments and to engage in mathematics, in ways that meet the needs of that individual's life as a constructive, concerned, and reflective citizen." That means the emphasis in PISA is "on mathematical knowledge put into functional use in a multitude of different situations and contexts" (Blum et al,2002). Therefore, mathematising real situations as well as interpreting, reflecting and validating mathematical results in 'reality' are essential processes when solving literacy-oriented problems. An important part of ML is using, doing, and recognizing mathematics in a variety of situations. In dealing with issues that lend themselves to a mathematical treatment, the choice of mathematical methods and representations often depends on the situations in which the problems are presented. Teachers of mathematics often complain that students have difficulty applying the mathematics they have learned in different contexts. Students should be offered real-world situations relevant to them, either real-world situations that will help them to function as informed and intelligent citizens or real-world situations that are relevant to their areas of interest, either professionally or educationally.

To provide a clearer picture of literacy in mathematics, it seems wise to reflect for a moment on what constitutes mathematics. Steen (1990) observed that traditional school mathematics picks a very few strands (e.g., arithmetic, algebra, and geometry) and arranges them horizontally to form the curriculum: first arithmetic, then simple algebra, then geometry, then more algebra and, finally, as if it were the epitome of mathematical knowledge, calculus (Delange, 1997). Each course seems designed primarily to prepare for the next. These courses give a distorted view of mathematics as a science; do not seem to be related to the educational experience of students. Mathematical concepts, structures, and ideas have been invented as tools to organize phenomena in the natural, social, and mental worlds. If we look at mathematics as a science that helps us solve real problems, it makes sense to use a phenomenological approach to describe mathematical concepts, structures, and ideas. This approach has been followed by Freudenthal (1973) and by others such as Steen (1990), who state that if mathematics curricula featured multiple parallel strands, each grounded in appropriate childhood experiences, the collective effect would be to develop among children diverse mathematical insight into the many different roots of mathematics .Steen then suggested that we should seek inspiration in the developmental power of five deep mathematical ideas: dimension, quantity, uncertainty, shape, and change. The OECD PISA mathematics expert group has adapted these, creating four phenomenological categories to describe what constitutes mathematics: quantity, space and shape, change and relationships, and uncertainty (Delange, 2003).

In Each Categories is expected that students be able to:

Quantity: The learner is able to use knowledge of numbers and their relationships to investigate a range of different contexts which include financial aspects of personal, business and national issues.

Change and relationships: The learner is able to recognize, interpret, describe and represent various functional relationships to solve problems in real and simulated contexts.

Space and shape: The learner is able to measure using appropriate instruments, to estimate and calculate physical quantities, and to interpret, describe and represent properties of and relationships between 2-dimensional shapes and 3-dimensional objects in a variety of orientations and positions.

Uncertainty: The learner is able to collect, summaries, display and analyze data and to apply knowledge of statistics and probability to communicate, justify, predict and critically interrogate findings and draw conclusions(National Curriculum of Republic of South Africa,2008).

Cognitive style

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 et al. 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 and Goodenough 1981; Saracho 1998,Alamolhodaei,2009, Amani et al,2011).

Witkin and Goodenough, (1981) Research shows that, in general, field dependent children and adults have a more social or interpersonal orientation than field independent people who prefer solitary situations to social ones (Coates et al., 1975; Ruble and Nakamura, 1972; Saracho, 1985a, 1985b, 1986,1989). Additional studies have found that, in contrast to FI individuals, FD people describe self and others more positively, have a greater preference for people oriented/humanistic vocations, learn social material more easily and demonstrate greater self-disclosure and cooperativeness (Oltman et al., 1975; Schleifer and Douglas, 1973; Sousa-Poza et al., 1973). Other research has shown that, in comparison to FD individuals, FI adolescents pay less attention to social cues and prefer vocations that require high autonomous functioning and analytic thinking (Witkin and Goodenough, 1981; Witkin et al., 1977).

Several researchers have demonstrated the importance of field dependency in science education and mathematical problem solving, in particular word problems (Talbi, 1990; Johnstone and Al-Naeme, 1991, 1995; Alamolhodaei, 1996; Sirvastava, 1997; Ekbia and Alamolhodaei, 2000; Alamolhodaei, 2002, 2009). 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, in particular word problems.

Research Framework

The main aim of the present study is to investigate students' ML in elementary, secondary and high school and its relationship with students' mathematical performance. Also according the relationship that exists between mathematical performance and cognitive style. This study investigates this relationship for ML. Therefore, the following objectives were sought:
The first objective of this study was to discover students' mathematical literacy in different level (K5, K8, and K11) and its relationship to students' mathematical performance.
The second objective of this study was to explore the relationship between field-dependency and mathematical literacy.

2. Material and Methods

Participants

The sample group of the present study comprise 281 students of both girls and boys (90 students aged 11-12 years old, 118 students aged 14-15years old and 70 students aged 17-18 years old).for this purpose, random sampling was used.

Procedures

The research instruments were:
(1) Mathematical Literacy test
(2)Group Embedded Figures Test (GEFT) (Oltman et al,1971)

Mathematical Literacy test

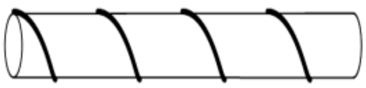
Field study to evaluate students' ML, was made of the items of reported advanced TIMSS and PISA questions and textbooks of three grade with the following criteria:

1. Math questions in four categories (two questions in each category) were selected.
2. Mathematical content that students required to solve problems have learned already or at the same grade.
3. Difficulty level of questions is determined based on experience of teachers and was about difficulty level of the textbook questions.

Sample questions

Space and shape: high school

1- A string is wound symmetrically around a circular rod. The string goes exactly four times around the rod. The circumference of the rod is 4cm and its length is 12cm. Find the length of the string. Show all your work.



Uncertainty: secondary school

2- In a bag of cards 1/6 are green,1/12 are yellow,1/2 are white and 1/4 are blue. If some one takes a card from the bag without looking, which color is it must likely to be?

Quantity: elementary school

3- Reza wanted to use her calculator to add 1379 and 243. He entered 1279+243 by mistake. What could he do to correct the mistake?

Change and relationships: elementary school

4- ☐ represents the number of magazines that Maryam reads each week. What represent the total number of magazines that Maryam reads in 6 weeks?

Mathematical performance

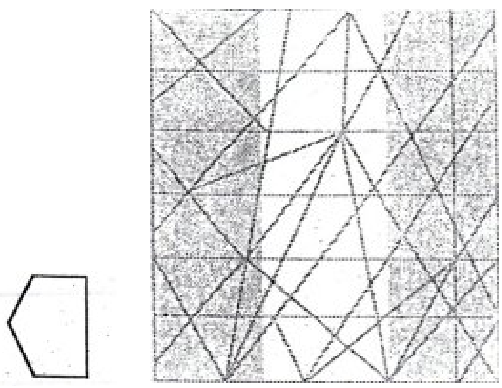
What was considered as a general mathematical performance mid-term grades or the last quiz grade students that was received from the school of their studies.

Cognitive styles measure

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 GEFT (Oltman et al,1971). On the test, subjects are required to disembeded a simple figure in each complex figure. There are 8 simple and 20 complex figure wich make up the GEFT. Each of the figures is embedded in several difrent complex ones. The student's cognitive styles were determined according to a criterion used by (Alamolhodaei 1996). Following the below create the categories (FD,FI,Fint).Who may be located between two style were labeled field-intermediate(Fint).

1) FD<Mean-1/4 SD(Standard Deviation)
2) FI>Mean+1/4SD
3) Mean-1/4 SD <Fint< Mean+1/4SD.

Example: students should find the simple figure in complex figure.



3. Results

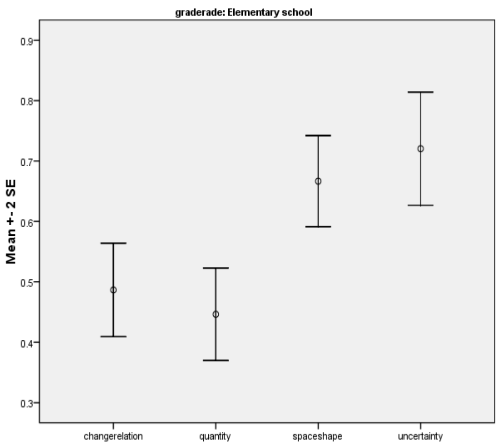
The first objective of the study was to discover students' Mathematical Literacy (ML) in different level (K5, K8, K11) and Its relationship to students' mathematical performance. According to Friedman test, there was significant difference between students' ML in different category (Quantity, Change and relationships, Space and shape and Uncertainty) at P-values less than 0.001 for each levels. Graphs of error bars shown that students' ML was better in uncertainty class for K5 students and their lower performance was occurs in quantity group. Although there wasn't significant difference between students' mathematical literacy in these groups: 1-Change and relationships and Quantity 2- Space and shape and Uncertainty.

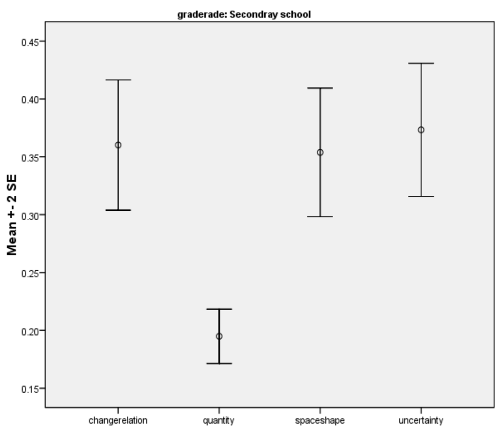
According to Graphs of error bars for K8 students, It can be seen that their ML was lower in groups of Quantity than other parts. And there was no significant difference between students ML in other groups, Although their performance was better in class of Uncertainty in this sample.

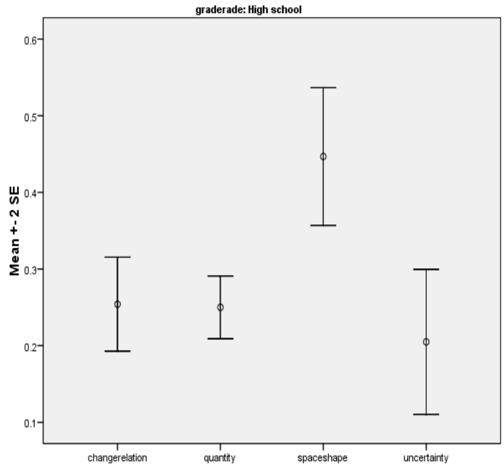
Finally, for K11 students, It can be seen that their ML was significantly better in group of Space and shape. In other hand their lower performance happened in class of Uncertainty.

Obtained results indicated that students' ML in these three levels was better in group of Space and shape in contrast to group of Quantity.

Figure1. Students' mathematical literacy in different levels

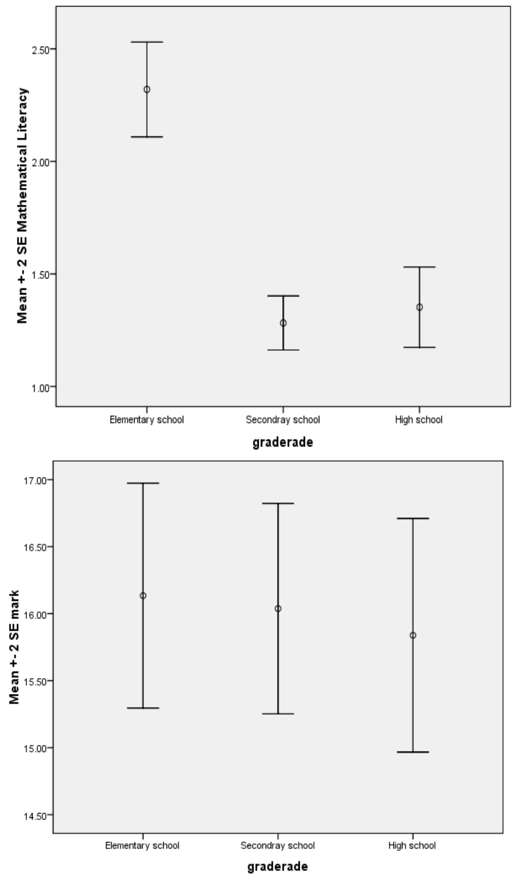






Obtained results according to Kruskal–Wallis one-way analysis of variance, shown that there wasn't any significant difference between students mathematical performance between these three levels(P-value: 0.472) but for their ML the results was different (P-value: Less than 0.001). According to Figure.2 students' ML was significantly better for K5 students.

Figure2. Comparison between Students' mathematical literacy and mathematical performance



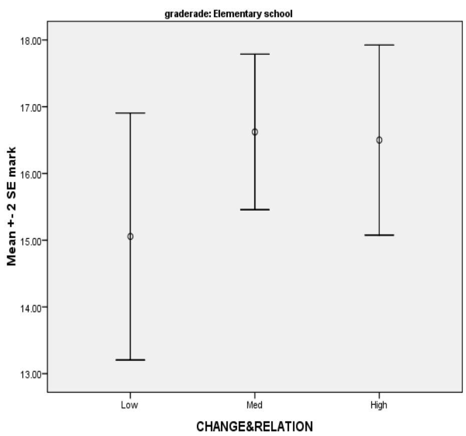
For better understanding the relationship between mathematical performance and ML, students' ML was categorized in three groups (low, medium, high): As mentioned above, for each category of ML two questions have been designed for each levels. Students who didn't answer to any questions in a category was placed in low ML concern to that group and student who answer half of a question or completely answer one question was placed in medium groups and students' who scored 1.5 or 2 points was placed in third group.

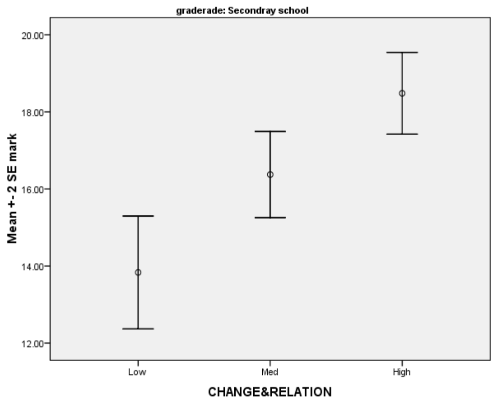
Table1. Mathematical performance & Mathematical literacy in different levels

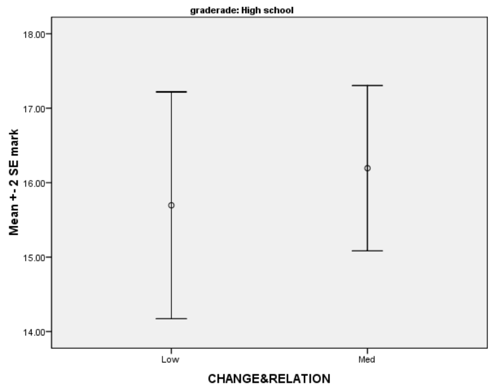
Title	K5	K8	K11
Mathematical performance & Change and relation	.251	Less than .001	.413
Mathematical performance & Quantity	Less than .001	.002	.092
Mathematical performance & Space and shape	Less than .001	.014	.782
Mathematical performance & Uncertainty	.340	.013	.127

According to Kruskal–Wallis one-way analysis of variance, which is provided in Table.1 can be seen that students' mathematical performance have significantly effects on students' ML in group of Change and relationships for K8 students. For other levels there wasn't a significant effect between these two variables. Although in this sample, according to Figure.3 students' with high mathematical performance had better ML in group of Change and relationships.

Figure.3 Change and relationships & mathematical performance in different levels

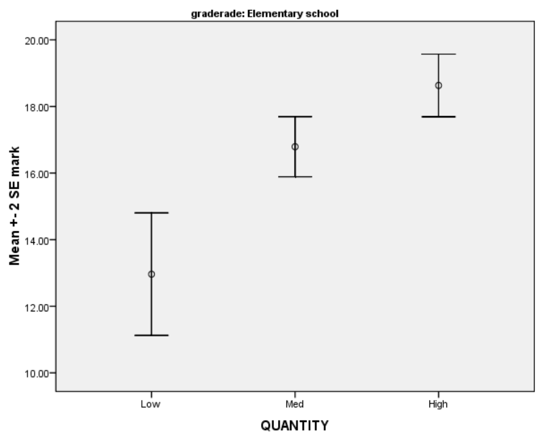


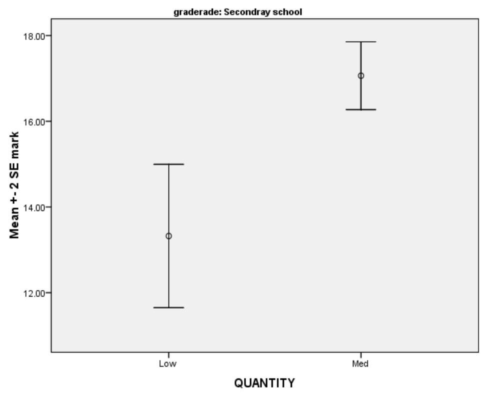


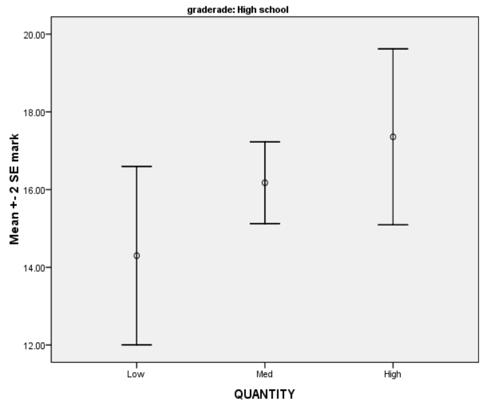


Students' mathematical performance have significantly effects on students' ML in group of Quantity for K5 and K8 students at 0.05 level and at 0.1 level for K11 students according to Table.1.Based on Figure.4, can be seen that students' with high mathematical performance had better ML in group of Quantity.

Figure.4 Quantity & mathematical performance in different levels

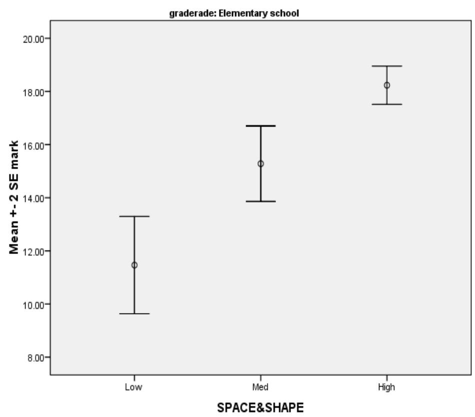


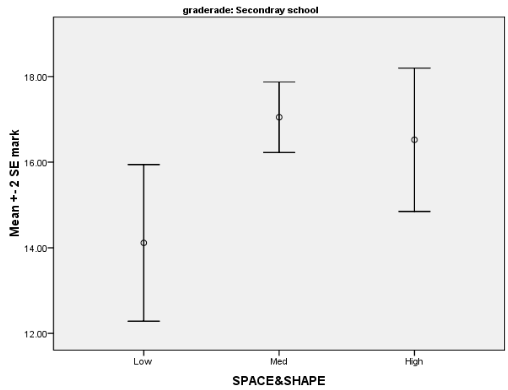


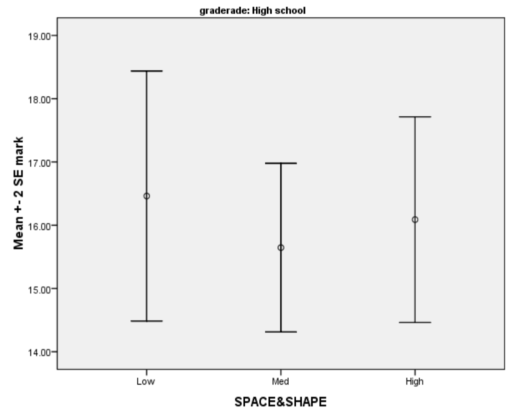


Students' mathematical performance had significantly effects on students' ML in group of Quantity for K5 and K8 students at 0.05 levels but for K11 students there wasn't any significant relationship between students' mathematical performance and ML. Figure.5 has shown these relationships more precisely.

Figure.5 Space and shape & mathematical performance in different levels

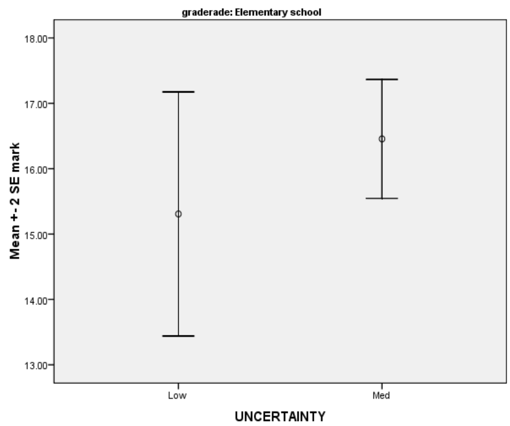


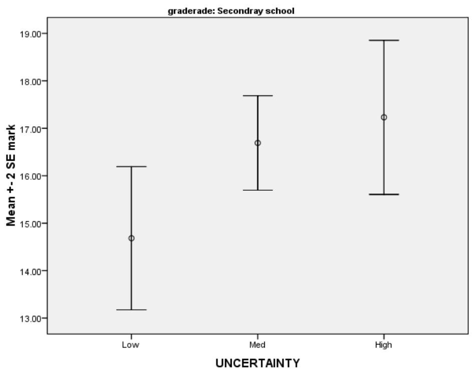


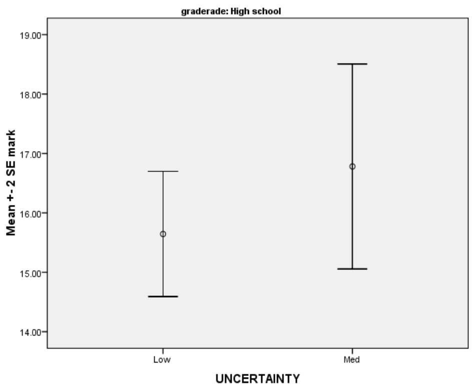


For group of Uncertainty, results of Table.1 shown that there is significant relationship between students' ML and mathematical performance for k8 students. For other levels, no significant results obtained. Although in this sample, according to Figure.6 students' with high mathematical performance had better ML in group of Uncertainty.

Figure.6 Uncertainty & mathematical performance in different levels







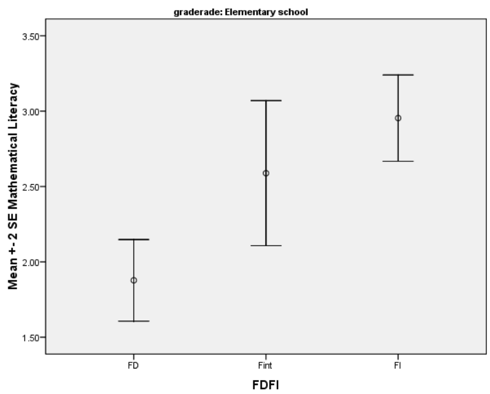
Finally, Spearman correlation between students' mathematical performance and students' ML was conducted .According to Table.2 the correlation between students' mathematical performance and ML for k5 and k8 was significant but the positive correlation between these two variable wasn't significant for k11 students. Indeed, researchers should note that according to Fisher's Z transformation test, the correlation between students' mathematical performance and ML for K11 was significantly lower than other levels.

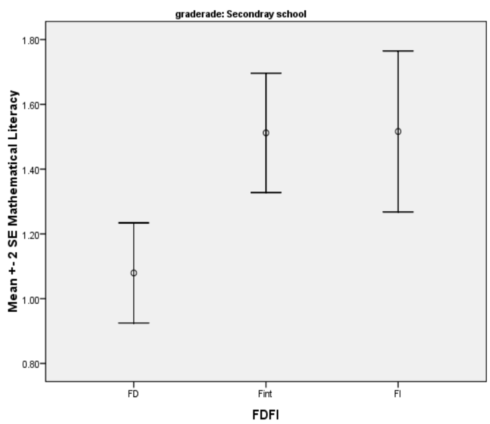
Table2. Correlation between Mathematical performance & Mathematical literacy in different levels

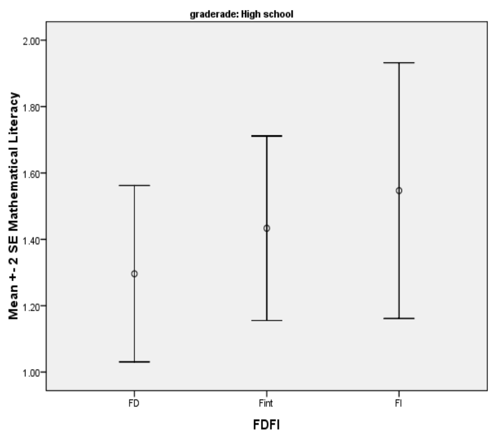
Title	P-value	Spearman Correlation
Mathematical performance & Mathematical literacy for k5	Less than .001	0.49
Mathematical performance & Mathematical literacy for k8	Less than .001	0.51
Mathematical performance & Mathematical literacy for k11	.142	0.18

The second objective of this study was to explore the relationship between field-dependency and ML. Obtained results from Kruskal–Wallis one-way analysis of variance for FD/Fint/FI groups and students' ML, shown that there was significant difference between students' ML according to their field dependency for K5(P-value =less than .001) and K8 (P-value =.001) while for K11 students' no significant difference obtained ((P-value =0.462). Figure.7 has shown these differences much better.

Figure.7 Field dependency & Mathematical literacy







Also Spearman correlation between GEFT scores and students' ML was conducted. According to Table.3 the correlation between students' field-dependency and ML for all levels was significant. Indeed, researchers of this study should note that according to Fisher's Z transformation test, the correlation between students' GEFT scores and ML for K11 was significantly lower than other levels (K5, K8).

Table3. Correlation between Mathematical literacy & GEFT scores

Title	P-value	Spearman Correlation
GEFT scores & Mathematical literacy for k5	Less than .001	0.50
GEFT scores & Mathematical literacy for k8	Less than .001	0.31
GEFT scores & Mathematical literacy for k11	.037	0.23

4. Discussions

In this study, elementary school students were significantly better than secondary school students in Mathematical Literacy (ML) test. In comparison with traditional school mathematics, ML is less formal and more intuitive, less abstract and more contextual, less symbolic and more concrete. ML also focuses more attention and emphasis on reasoning, thinking, and interpretation compared to traditional education. Therefore, students do not reach necessary math insight which may help them for meaningful learning.

Elementary school students are less engaged their own in formulas and stereotypes and they solve mathematics problems with more Common sense. This may cause them to better performance in ML test. Researchers have admitted that traditional education rather than training Common sense of students, involves them with formulation and solution of such stereotypes that they are in the Choice and initiative of problem-solving strategies in trouble. Secondary And high school Iranian textbooks have been changes in the problem solving orientation. Approach of problem solving which considered in Iranian textbook will increase ability of students to deal with real issues of life. But according to teachers, no significant change in student problem solving ability observed. Perhaps the reason is that problem-solving strategies do not still influence to the textures of Iranian textbooks, and materials are not homogeneous. Apparently the real world from the perspective of the authors has been imposed to the textbooks.

Elementary school students in the uncertainty class have high performance and in the quantity class have low performance. The reason that their teachers expressed was this: The items and problems of Quantity are not tangible for students. The teaching style of quantity section of the text book in not lead to meaningful learning and less quantity type questions has been paid in practical problems. Despite uncertainty is few tackled in elementary textbook, elementary school students have good performance because relevant issues were tangible so easier to understand for them.

Secondary school students expected to have good performance in solve the problems category of change and relationship because Iranian textbook thoroughly emphasis and devoted volume to this topic and regarding to math exams this topic has been highlighted . However, students have not a good understanding of the change and relationships and can't show good understanding within practical issues and their understanding of the function is weak.

Elementary and secondary school students' were relatively shown good performance in uncertainty category but high school students' shown weak performance in this category. Perhaps, in the elementary and secondary school, math problems are more tangible and could be solved with common sense ,But in high school textbook, issues are more complicated and therefore students have less readiness to tackle such problems.

Also, this study shown that students with a better general mathematical performance were better in ML test. This correlation was stronger in elementary and secondary levels in contrast to high school. This may be due to this fact that students in high school are more dependent to formulation and stereotypes strategies than lower levels.

According to this study, FI students exhibited higher scores than FD learners in ML test. It seems to the researcher that the qualities of questions of ML are more suitable for FI thinking style. Because the questions of ML test posed in the field removed from the state of the routine and stereotype and required to separate the fields of information and needed analysis and interpretation, FI students to solve such problems are better capable than FD students. Math problem solver must be able to convert the problem into a mathematical model, so FD students than FI students will have more problems to these types of question. This part of results of this study are similar with previous studies that shown school students with FI cognitive style achieved much better results than FD ones in mathematical problem solving (Talbi, 1990; Johnstone and Al-Naeme, 1991, 1995; Alamolhodaei, 1996; Sirvastava, 1997; Ekbia and Alamolhodaei, 2000; Alamolhodaei, 2002, 2009).

The role of textbooks in the focused educational system is highlighted, so this role in promoting the ML of students is clear. But neither teachers nor students because of the traditional style, and get accustomed to it, they are not prepared at applying the active method and they need time to be consistent with these changes. According to teachers, still issues raised in the textbooks are away from the issues that students involved in real life and do not motivate them .Teachers suggest reducing unnecessary mathematics and mathematical content that less needed in life, so they can be pay more attention to habit-forming processes such as problem solving and a positive attitude to mathematics in students. A lot of math teachers believed that questions related to students' real life could be very helpful in teaching and learning mathematics. Much of the mathematics taught in grades 7 to12 is there because it is important outside the math classroom. Foundation applications, like paths of projectiles, should not be stripped away, but rather should be used to motivate the arithmetic, algebraic, or geometric concepts. Further, students should have an opportunity to see a broad expanse of math applications so they can find links between their interests and aspirations and their mathematics coursework (Glazer & McConnell, 2002).

Corresponding Author:
Dr. Hassan Alamolhodaei
School of Mathematical Sciences, Ferdowsi
University of Mashhad, Iran
Alamolhodaei@yahoo.com

References

1.Alamolhodaei, H. (1996). A study in higher education calculus and students learning styles.Ph.D.Thesis. University of Glasgow, Glasgow, UK.

2.Alamolhodaei, H.(2002). Students'Cognitive Style and Mathematical Word Problem Solving. Korea Society of Mathematical Education, 6, 171-182.

3.Alamolhodaei, H.(2009). A working memory model applied to mathematical word problem solving. Asia Pacific Educ, 10, 183-192.

4.Amani , A, Alamolhodaei, A,Radmehr, F.(2011). A gender study on predictive factors of mathematical performance of University students. Educational Research.2:6.1179-1192

5.Blum,W. & et al.(2002). ICMI STUDY 14:Applications and Modeling Mathematics Education – Discussion Document. Educational Studies in Mathematics, 51, 149-171.

6.Coates, S., Lord, M. Jakabovics ,E. (1975) . Field dependence independence , social non-social play and sex differences in preschool children. Percept, and Motor Skills ,47, 203-208 .

7.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, 145–152. doi:10.1080/0263514850030107.

8.DeLange,J. (2003). Mathematics for Literacy. In B.L.Madison & L.A Steen Literacy. Why Numeracy Matters for School and Colleges, 75-89.

9.DeLange,J.(1997). Framework For Classroom Assessment in Mathematics. Chapter 6. Freudenthal Institute and National Center for Improving Student Learning and Achievement in Mathematics and Science.

10.Ekbia, 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, Teacher Training University of Tehran, Iran.

11.Glazer, E. M & McConnell, J. W. (2002). Real Life Math - Everyday Use of Mathematical Concepts. Greenwood Press. London

12.Johnstone, AH. Al-Naeme, FF. (1991). Room for scientific thought. Int. J. Sci. Edu, 13(2), 187– 192.

National Curriculum Statement Grade 10-12 (General). Learning Programe Guidelines 13.Mathematical Literacy (2008). Department: Education Republic of South Africa.

14.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:10.1080/09500699601 80503.

15.Oltman, P. Goodenough, D. Witkin, H. Freedman, N. Friedman, F. (1975). Psychological differentiation as a factor in conflict resolution. J.Pers. Soc. Psychol. 32, 730-736 .

16.Oltman PK, Raskin E, Witkin HA (1971). A manual for the embedded figures test. Palo Alto, CA: Consulting Psychologists Press, Inc.

17.PISA 2003 sample question files
URL: http://www.pisa.oecd.org.

18.Ruble, D. Nakamura, C. (1972). Task orientation versus social orientalion in young children and their attention to relevant social cues. Child Develop. 43, 471-480.

19.Saracho, O. (1985a) . A modification of the ABC scale. J. Personal. Assess. 49, 154-155.

20.Saracho ,O. (1985b). Young children's play behavior and cognitive slyle. Early Child.Develop. Care. 22, 1-18.

21.Saracho, O. (1986) . Validation of two cognitive measures to assess field dependence/ independence. Percept. Motor Skills. 63, 255-263.

22.Saracho, O. (1989) . The factorial slructure of three-to-five year old children's social behavior: Cognitive style and play. J. Res. Develop. Educat. 22, 21-28.

23.Sousa-Poza, J. Rohrberg, R. Shulman, E. (1973). Field dependence and self-disclosure. Percept. Motor Skills. 36, 735-738 .

24.Talbi, MT.(1990). An information processing approach to the investigation of mathematical problem solving at secondary and university levels. Ph.D. Thesis, University of Glasgow, Glasgow, UK.

25.Witkin, H. Goodenough, D. (1977) . Field dependence and interpersonal behavior. Psychol. Bull. 4, 661-689.

26.Witkin ,H. Goodenough ,D. (1981). Cognitive Styles: Essence and Origins. International Universities Press Madison, CT.

3/24/2012