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Students' Field-dependency and Their Mathematical Performance based on Bloom's Cognitive Levels

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Students approach mathematical problem solving in fundamentally different ways, particularly problems requiring conceptual understanding and complicated strategies. The main objective of this study is to compare students' performance with different thinking styles (Field-dependent vs. Field independent) in mathematical problem solving. A sample of 242 high school males and females (17–18 years old) were tested based on the Witkin's cognitive style (Group Embedded Figure Test) and by a math exam designed in accordance with Bloom's Taxonomy of cognitive level. The results obtained indicated that the effect of field dependency on student's mathematical performance was significant. Moreover, *field-independent* (FI) students showed more effective performance than *field-dependent* (FD) ones in math tasks. Male students with FI styles achieved higher results compared to female students with FD cognitive style. Moreover, FI students experienced few difficulties than FD students in Bloom's Cognitive Levels. The implications of these results emphasize that cognitive predictor variables (FI vs. FD) could be challenging and rather distinctive factor for students' achievement.

Keywords: cognitive style, field-dependent/field-independent, mathematical mistakes, Bloom's cognitive taxonomy, Group-Embedded Figures Test (GEFT)
MESC Classification: C34
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1. INTRODUCTION

Many students have negative feelings towards math learning and problem solving. They usually complain that their teachers and their notes are hard to understand. Very many students may remember a few mathematical concepts that have been taught, but they frequently never learn at the time of teaching (Alamolhodaei, 1996).

Teaching math often caused students to memorize abstract materials with a meaningless understanding and therefore face problem solving difficulties.

Reasoning and problem solving are closely related topics which are both important in math learning. In learning mathematics, students should create all the concept definitions —which are made by the mathematicians of the past—from the scratch in their own minds (Skemp, 1986).

In situation of formal learning mental conflict may be occurred between individual concept images and math defined concept (Vinner, 1991). This could be a main source of students' difficulties and misconceptions in learning mathematics and problem solving (Alamolhodaei, 1996).

As Leinhardt, Zaslavsky & Stein (1990) noted, misconceptions are features of students knowledge; a specific part of mathematical ideas that may or may not have been taught. For example, students desire, frequently, the function to be defined by a single formula and they are uneasy when dealing with piece wise functions, or their tendency to recognize only one-one correspondences as function definition (Ferrini-Mundy & Lauten, 1994; Alamolhodaei, 1996).

Three major sources of students' difficulties in mathematical activities may be suggested that are conceptual understanding, mathematical language and notations, and started on mathematical proofs (Moore, 1994; Alamolhodaei, 2009a; 2009b).

Cognitive style and mathematical performance

In recent years the study of cognitive styles has become a broad stream in mathematical performance. The results of studies in students' problem solving difficulties suggest that the style affects both the teachers' instruction and the students' learning (*e.g.*, Witkin *et al*., 1977; Srivastava, 1997; Alamolhodaei, 1996; 2001; 2002; 2009a; 2009b).

Cognitive style is an individual approach to organizing and representing information, and the way in which a student seeks solutions to problems (Riding & Al-Sanabani, 1998; Saracho, 1998; Price, 2004). Cognitive styles are a form of identifying individual differences and define consistencies in the individuals' means of using their cognitive processes. According to Saracho (1997; 2003), cognitive style conveys a consistent way of information processing by a learner and a series of responses to a variety of situations.

One cognitive style may lead to more effective learning and problem solving to one discipline, but may be detrimental to another discipline.

A student with an analytic thinking style may succeed in a task requiring analytical skills whereas a student with a global thinking style may fail in the same task (Saracho, 1998). Therefore, one of the most features of a cognitive style is to explain students' difficulties with the nature and complexity of mathematical performance (Alamolhodaei, 2002).

FD/FI Cognitive Style and Mathematical Problem Solving

A widely used dimension of cognitive style in science and math education is Field-Dependence/Field-Independence (FD/FI) which specifies an individual's mode of perception, thinking, problem-solving, and remembering.

This dimension of cognitive style was oriented in Witkin's work (Witkin, 1977; Witkin, Noore, Goodenough & Cox, 1977; Witkin & Goodenough, 1981). It has extensively been studied by several researchers and has a wide application in educational problems (Rollock, 1992; Tinajero & Paramo, 1997; Ekbia, 2000; Saracho, 2003; Alamolhodaei, 1996; 2002; 2009a; 2009b).

Witkin & Goodenough (1981) describe FD as an individual who has difficulty in separating an item from its context. Whereas, FI is a person who can easily break up an organized field and separate relevant material from its context or discern signal from noise in a confusing background (Johnstone & Al-Naeme, 1991). FDI dimension identifies the FD/FI learners' distinct approach to process and refines information. They cognitively respond differently to complex and confusing situations (Saracho, 2003). FI students are able to structure an analytical task, whereas FD students are better in a context where problems and learning is already structured and analyzed for them.

Field-independent learners are characterized as operators with an internal frame of reference, intrinsically motivated with self- directed tools, structuring their own learning, and defining their own strategies. On the other hand, FD learners are relying more on an external frame of reference, are extrinsically motivated, respond better to clearly defined performance goals that require structuring and guidance from instructor, and a desire to interact with other learners (Cassidy, 2004).

Several studies have demonstrated the importance of field dependency in mathematical activities (*e.g.*, Talbi, 1990; Witkin, Noore, Goodenough & Cox, 1977; Srivastava, 1997; Ekbia, 2000; Alamolhodaei, 1996; 2001; 2002; 2009a; 2009b). It was found that FI students tend to get higher results than FD Students in mathematical problem solving, in particular word problems. Moreover, undergraduate students with FI thinking style achieved better results than FD ones in calculus problem solving at higher education levels.

The present study

The main aim of the present study was to identify students' mathematical performance with different FD/FI thinking style based on Bloom's Cognitive Taxonomy (1956).

Thus, the main question addressed in this study is:

> "Is there any difference between students' mathematical performance with FD/FI thinking style in different mathematics tasks based on Bloom Taxonomy?"

It seems to the researchers, as a main hypothesis, that FI students would be expected to show higher results and few mistakes than FD students in mathematical problem solving. Moreover, FI students' performance in mathematical tasks comprising Bloom's Cognitive Taxonomy could show fewer difficulties than FD students. In addition, male students could exhibit more math mistakes than female ones in each thinking style.

METHOD

Participants

The sample group of this study comprises 242 high school males and females (17–18 years old) who were selected from five high schools at the Guilan Province in the north of Iran. They were 102 female and 140 male. For this purpose random multistage stratified sampling design was used.

Procedures

The research instruments were:

1) *Group-Embedded Figures Test* (GEFT) (Oltman, Raskin & Witkin, 1971).
2) Mathematics exam

Cognitive Styles Measure

The independent variables were cognitive style and the position of a learner in relative to each of the learning style dimensions (FD and FI) was determined using the GEFT (Oltman, Raskin & Witkin, 1971).

The test and subjects were required to dissemble a simple figure in each complex figure. There were 8 simple and 18 complex figures, which made up the GEFT. Each of the simple figures was embedded in several different complex ones.

Students' cognitive styles were determined according to a criterion used by Scardamalia (1977), Case (1974), Globerson (1974), Johnstone, Hogg & Ziane (1993), and Alamolhodaei (1996). Students who had a score less than ¼ standard deviation (SD) below the mean were classified as field dependent (FD).

In order to create the category of field independence, students had to score at least ¼ SD above the mean for the sample population. The intermediate scores were assigned to (Mean ± ¼ SD) those who may be located between the above two styles (FD & FI) and were labeled as field-intermediate (FInt) learners.

Table1 shows the number of students in each of the three dimensions (FD/FInt/FI) in this sample.

To maximize the effect of cognitive styles, only the results of FD group were compared to that of FI style and the intermediate group was ignored.

Reliability for the GEFT has been estimated to be 0.60 (Oltman, Raskin & Witkin, 1971). An example of GEFT is shown in Appendix I.

Table 1. The distribution of FD, FInt and FI over the students' sample

Group	FD	FInt	FI
Total (n = 242)	n = 50	n = 26	n = 166
%	20.7%	10.7%	68.6%

Mathematics Examination

The effectiveness of FD/FI cognitive styles was investigated by the students' performance in mathematical problem solving. Thus a math exam with fifty questions as dependent variables was designed. The questions were based on the Bloom's Cognitive Taxonomy consisting of six skill levels of learning (Appendix II). These levels increased in complexity in the following order: knowledge, comprehension, application, analysis, synthesis and evaluation. Knowledge refers to the simple recall of facts, definition or terms. When facts are grouped, compared, interpret, described or even explained, then this is comprehension. Learning objectives at this level are: understanding facts and principles interpretation of material and translation of verbal material to mathematical formulae. By building knowledge and comprehension, one moves to application that is the ability to apply previously acquired knowledge to a new situation. Analysis, the fourth skill level, requires the ability to break down the material into its components, identify parts, and make relationships between parts to reach a reasonable conclusion. With sufficient experience in the area of analysis, one can learn to develop one's own reasonable solutions; this is referred to as synthesis. The pinnacle of Bloom's Taxonomy is evaluation, where one makes qualitative and quantitative judgments based on evidence;

critical thinking. The first two categories in the cognitive domain, knowledge and comprehension, are not rigorous. They are concerned with the student's ability to learn basic information and demonstrate understanding of new material in math. It can also be argued that application is not rigorous since it is concerned with the direct usage of known strategy and information to solve something that might be similar. Rigor requires students to be more interactive with the mathematical materials. Analysis, synthesis and evaluation, all are formed by math questions that contain rigorous qualities. The maximum score for math exam was 50, normality assumption for the exam was considered $(P > 0.2)$. Math exam had six tasks with 8 score for each of them, except the evaluation task which was allocated 10 score.

On designing an appropriate and reasonable method for assessing students' mistakes in math performance, a lot of problems were experienced. To overcome these, the authors decided to use a method that could be taken by other mathematicians and researchers to obtain nearly the same results. To this end, students' mistakes in math exam were considered. In other words, each student was assigned a negative score for every mistake he/she made. The summation of negative scores was then determined for Bloom's Taxonomy levels and the math exam as whole.

Results

In this study, female students exhibited higher mean score in GEFT compared to male students. Table 2 shows the result.

Table 2. Mean and SD for the scores male and female students obtain in GEFT

Group	Mean	SD
Male (*n* = 140)	15.74	3.43
Female (*n* = 102)	16.95	5.67

Table 3. Sex distribution for Total FDI cross tabulation

Group	Mean	FInt	FI
Male number	36	17	87
% within sex	25.7%	12.1%	62.1%
% within Total FDI	72.0%	65.4%	52.4%
Female number	14	9	79
% within sex	13.7%	8.8%	77.5%
% within total FDI	28.0%	34.6%	47.6%

The sex distribution of FD/FInt/FI (FDI) over the students' sample is shown in Table 3. According to Chi-square test at 5 percent of error level and p = 0.03, FDI thinking styles were related to students' sex. As shown in Table 3, 77.5% of female (F) students were FI, while 62.1% of male (M) students were FI. This means that female students tended to be FI compared to male ones.

Moreover, male students exhibited high mean score (17.02) superiority in math exam compared to female ones (16.08) at $p = 0.26$, which was not statistically significant.

To find whether FI students would exhibit higher results than FD students in mathematical problem solving, the mean and SD for mistake scores on math exam and Bloom's levels were related to FD/FI thinking style as set out in Table 4. As can be seen, each student had two types of scores; one for her/his mistakes at each level and one for the overall correct answers in the exam.

Table 4. Mean and SD for FD/FI students' mistake in math exam

Group	FI		FD	
Blooms' Levels	Mean	SD	Mean	SD
Knowledge[1]	2.28	1.97	3.98	2.05
Comprehension[2]	3.50	1.96	4.28	2.25
Application[3]	2.38	2.32	3.30	2.41
Analysis[4]	2.59	2.51	4.62	2.55
Synthesis[5]	3.30	2.51	4.70	2.74
Evaluation[6]	3.40	3.5	3.78	2.90
Math exam[7]	18.21	4.31	24.68	12.41

Note: 1. $p < 0.00$ 2. $p = 0.01$ 3. $p = 0.01$ 4. $p < 0.00$ 5. $p = 0.002$ 6. $p = 0.45$ 7. $p = 0.002$

The data in of Table 4 confirm the superiority performance of FI students over FD ones at all Bloom's Cognitive levels of math activities. In other word, at all six parts of Bloom's cognitive levels the FI students' mean for mistake scores was less than FD students. However, despite of the superior performance of FI students in all cognitive domains, it seems that students with either thinking style have a lot of difficulties for such math tasks. The situation for FD individuals is worse, particularly in comprehension, analysis and synthesis as well as math exam as a whole.

According to t-test results for mean scores on math mistakes, numbers of mistakes, a significant difference was found between two groups of FD/FI thinking styles at $p < 0.05$, except for, evaluation category with $p = 0.45$. It should be noted that normality assumption for math data was strongly confirmed.

Based upon Table 5, the male students obtained a higher mean mistakes compared to female ones. In other word, based on this result, male students tended to show two times more mistakes than female students in mathematical problem solving. T-test showed that the difference was significant at $p = 0.002$.

Table 5. M/F performance in math exam

Sex	*n*	Mean	SD
M	140	25.50	10.54
F	102	11.53	7.47

In addition, the comparison between performance of male and female students with different thinking style using Bloom's Cognitive levels was the other objective of the present study. The mean and SD for mistake scores on each level were related to FD/FI as set out in Tables 6 and 7. Based upon the t-test for the mean mistake scores at each level, a significant difference was found between male and female students with different thinking styles (FD/FI), at $p < 0.05$. These findings support the original research claim that female students would experience less difficulty in math tasks.

Table 6. Mean & SD for M/F students' mistakes with FD style

Cognitive style	Bloom's Level	Sex	*n*	Mean	SD	P-value
FD	Knowl.	M	36	4.33	2.07	0.04
		F	14	3.07	1.77	
	Comp.	M	36	4.86	2.00	0.003
		F	14	2.79	2.00	
	Appli.	M	36	3.92	2.34	0.003
		F	14	1.71	1.81	
	Analysis	M	36	5.44	2.15	0.001
		F	14	2.50	2.31	
	Synth.	M	36	5.50	2.42	0.001
		F	14	2.64	2.49	
	Eval.	M	36	4.28	2.98	0.049
		F	14	2.50	2.31	

Table 6 represents that male students with FD style exhibited more mistakes in comprehension, analysis, synthesis and evaluation. The same result was found for FI students of different sex.

Moreover, based on the mean scores of students in math exam in Table 8, the male students with FI style obtained higher scores compared to female students with the same style. A significant difference was found between two groups at P = 0.03. But, no significant difference was observed between math mean scores of FD and FI groups. This finding was in contrary to the results reported by other researches.

Table 7. Mean & SD for M/F students' mistakes with FI style

Cognitive style	Bloom's Level	Sex	*n*	Mean	SD	P-value
FI	Knowl.	M	87	3.56	1.84	0.001
		F	79	3.56	1.84	
	Comp.	M	87	4.25	2.01	0.001
		F	79	2.67	1.54	
	Knowl.	M	87	3.56	1.84	0.001
		F	79	2.08	1.82	
	Com.	M	87	4.25	2.01	0.001
		F	79	2.67	1.54	
	Appli.	M	87	3.38	2.41	0.001
		F	79	1.28	1.61	
	Analysis	M	87	3.89	2.47	0.001
		F	79	1.91	1.38	
	Synth.	M	87	4.57	2.35	0.001
		F	79	1.89	1.86	
	Eval.	M	87	5.06	3.20	0.001
		F	79	1.58	1.81	

Table 8. Mean and SD for the scores obtained by male & female students with FI style in math exam

Group	Male (n = 87)		Female (n = 79)	
Math Exam	Mean	SD	Mean	SD
	17.14	6.82	14.86	6.39

DISCUSSION

This study showed positive relationships between thinking styles (FD/FI) which are based on individual differences and students' performance mathematical problem solving. It was observed that FI students exhibited higher performance in mathematical task compared to FD students. Findings of this study support the previous claims that students with FI cognitive style achieved higher results than FD students in tackling the complexity of mathematical problems (Ekbia, 2000; Alamolhodaei, 2002; 2009a; 2009b).

In this study, female students tended to be FI compared to male students. The latter made more mistakes in mathematical problem solving than the former.

Moreover, male students with FI style exhibited higher performance in comparison to FI female students in math task. It was also observed that FD students tended to show weak performance with more mistakes in Bloom's Cognitive Taxonomy which consists of six levels of learning and problem solving. In spite of the superiority of FI learners, it is safe to suggest that students with different styles (FI vs. FD) showed performance difficulties in such mathematical tasks. This weakness was very remarkable in the analysis and synthesis tasks, in particular with FD learners. This means that all thinking styles need to be assisted to overcome with the complexity of questions that contain rigorous qualities such as analysis and synthesis. As can be inferred from the results of the present research, the FD/FI cognitive style is a more distinctive and challenging psychological variable to the learners with different thinking style. This means that as a math teacher, we should pay extra attention to how students think, learn and solve problems. In a real problem solving situation where signal and noise are both present and task demands are high, FD students may suffer a drop in performance. Therefore, necessary opportunity should be provided to all students (female/male) with different cognitive styles (FD/FI). They need to be assisted with performing suitable task and teaching method. Designing the questions based on cognitive domain of Bloom's Taxonomy is a step towards exposing students to more rigor, but higher order of thinking skills are not the only part of rigor. Students also need to interact with mathematical material that is emotionally challenging and encourage them to consider multi-conceptual meanings.

Recognizing some limitations of Bloom's Taxonomy (1956), some researchers have suggested modifications to it in order to make it compatible with the purpose of assessing students' performance in mathematics (Smith *et al.*, 1996; Porter, 2002; Rizvi, 2007). It would be valuable to continue this study in accordance with taxonomies/frameworks proposed by Bloom and others that recognize overlapping as well as discrete categories of cognitive processes. It is safe to suggest that teaching styles and mathematical tasks should be planned adaptable to cognitive style of learners particularly to FD students who need to be assisted to overcome mathematical problems difficulties in conceptual and procedural knowledge.

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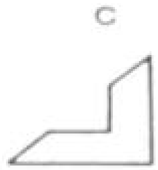
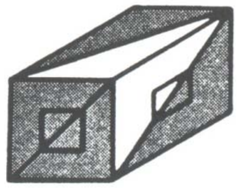
APPENDIX I
AN EXAMPLE OF GEFT





Simple Form "c" Find Simple Form "c"

APPENDIX II
SOME EXAMPLES OF MATH QUESTIONS BASED ON BLOOM'S TAXONOMY

Knowledge tasks:

1. Determine which of the following statements is true:
   a. Derivative of a function and differential is the same mathematical concept.
   b. Derivative is a limit, but differential is not.
   c. Differential is a limit, but derivative is not.
   d. Derivative is the same as instantaneous velocity
2. Determine which of the following relations is not true:
   a. $\log (a/b) = \log a - \log b$
   b. $\log ab = \log a + \log b$
   c. $\log (a - b) = \log a - \log b$
   d. $\log_5 a = 5 \log a$

Comprehension Tasks:

1. Consider set $A = \{\varnothing, \{\varnothing\}\}$, and determine whether each of the following is true or false:
   a. $\varnothing \in A$ b. $\varnothing \subset A$ c. $\{\varnothing\} \subset A$ d. $\{\{\varnothing\}\} \in A$
2. Determine whether each of the following statements is true or false:
   a. $N \subset Q \subseteq R$ b. $Q \subset Z \subseteq R$ c. $Z \subset Q \subseteq N$ d. $R \subset Z \subseteq Q$

3. State whether or not the following assignment defines a function:

   a. $Y = |x|$ b. $y = x$ c. $y = \sin x$ d. $y^2 = x$

Application Tasks:

1. Determine whether or not each relation below is a function from $\mathbb{R}$ into $\mathbb{R}$:

   a. $Y = \sqrt{x}$ b. $y^2 = x$ c. $|x| + |y| = 8$ d. $y = |x|$

2. Suppose A= {7, 8, 9} and B={7, 8, 11, 12}, determine whether each of the following statements is true:

   a. $A - B = \{7, 8\}$ b. $A - B = \{9\}$

   c. $B - A = \{7, 8, 11, 12\}$ d. $B - A = \{11\}$

Analysis Tasks:

1. If $a, b, c \in R$ and $c = d$ which of the following statements is always true:

   a. $ab = 1$ b. $ac = bd$ c. $ac > bd$ d. $a + c < b + d$

2. Determine which of the following is always a true statement:

   a. $\tan x + \cot x = 1$ b. $\sin x + \cos x = 1$

   c. $-1 \le \tan \le 1$ d. $\tan^2 x + \cot^2 x = 1$

Synthesis Tasks:

1. Let *A* and *B* a matrix, which of the following statements is not true:

   a. If $x > 0$ then $x^2 - x > 0$

   b. If $0 < x < 1$ then $x^2 - x > 0$

   c. If $0 < x < 1$ then $x^2 < x$

   d. If $x > 1$ then $x^2 - x < 0$

Evaluation Tasks:

1. Let $S = \lim_{x \to \infty} \frac{x^2 - 1}{2x^2 + 1}$. Determine which of the following the correct answer is:

   a. -1 b. $+1$ c. $\frac{1}{2}$ d. 2

2. Determine whether each of the following is the domain of fraction

$$g(x) = \frac{x^2}{x^2 + 1}$$

   a. $\mathbb{R}$ b. $\mathbb{R} - \{2\}$ c. $\mathbb{R} - \{-2\}$ d. $\mathbb{R} - \{-1, 2\}$