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Experimental Research about Effect of Mathematics Anxiety, Working Memory Capacity on Students' Mathematical Performance With Three Different Types of Learning Methods

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ABSTRACT

The purpose of this quasi-experimental was to investigate the effect of two predictive factors (mathematics anxiety, working memory capacity) on mathematical performance of three groups of college students with three different learning methods. Students in 1st group studied the material cooperatively; students in the 2nd group studied the material in e-learning method and students in 3th group studied the material in traditional class. Three chapter's tests were used to measure students' Mathematical achievement. The significant negative correlation between mathematics anxiety and mathematical performance and positive correlation between mathematical performance and working memory capacity were found. One of the results of this study showed that students in the cooperative learning groups had significantly higher test scores than students in the other groups. Moreover, there is a significant interaction effect of working memory capacity and mathematics anxiety on mathematical performance based on students' learning method. The most important result of this study indicated that with controlling the effect of math anxiety, WMC had significantly more effect on students' mathematical problem solving who studied their lessons in e-learning method than other groups of learning method.

Keywords: *Mathematics anxiety, Working memory capacity, Cooperative learning, e-learning, Mathematical performance.*

1. INTRODUCTION

The art of problem solving is the heart of mathematics. Mathematical problem solving is a complex cognitive activity involving a number of processes and strategies. Patton et al. [1] propose that learning to solve problems is a primary objective in learning mathematics, as problems are an inevitable fact of life. According to Effandi and Normah [2], a student needs to think and make decisions using appropriate strategies to solve mathematic problems. Many research studies and projects have pointed out the importance of learning problem solving in school mathematics courses [4-6].

The National Council of Teachers of Mathematics [5] recommendations to make problem solving the focus of school mathematics posed fundamental questions about the nature of school mathematics. Mathematics instruction should be designed so that students experience mathematics as problem solving.

Teaching mathematical problem solving is a challenge for many teachers. A teacher who believes that information can be transmitted to students' heads often employs lecture methods in the teaching of mathematics. These teachers usually stand up in front of the class, writing formulas on the board, and providing several examples for practicing the formula. Teachers then give students many exercises for practice and expect students to memorize the formula [7].Yet several studies have described the detrimental effects of this approach for students (e.g. [7, 8]). Because of a tendency for teachers to expect students to memories a lot of facts that may not necessarily make sense to them, and asking students to listen and practice many exercises in preparation for a test, many students come to the conclusion that mathematics is either about right or wrong, it is unrelated to real life, or it is only appropriate for smart students [7, 9].

According the importance of math problem solving the present study was carried out by the authors to study mathematical problem solving in term of predictive factor. In this study the effect of working memory capacity and mathematics anxiety on mathematical performance according to the learning method will be discussed. It seems to be more beneficial to describe the historical background of predictive factors of mathematical performance, working memory capacity and mathematics anxiety before introducing research framework.

a. Working memory Capacity

Alan Baddeley defines working memory (WM) as "a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" [10]. Working memory refers to a complex cognitive system that is responsible for the storage and processing of information in the short term. Also working memory known as a mental workspace,

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that involved in controlling, regulating, and actively maintaining relevant information to accomplish complex cognitive tasks (e.g. mathematical processing) [11]. Working memory capacity (WMC) is essential for important cognitive abilities including reasoning, comprehension and problem solving [12].

There is a weight of evidence suggesting that working memory is a good predictor of mathematical skills [13-15]. There is also direct evidence that WMC has an impact on children's ability to perform mathematical tasks at school. Gathercole and co-workers [16, 17] found significant impairments in WMC in a group of children who had scored below the expected level in national mathematics tests at age 7. Moreover, [18-20] have found that the students with high WMC are more capable of solving math word problems compared to those with low WMC.

b. Mathematics anxiety

Math anxiety is described as "feelings of tension and anxiety that interfere with the manipulation of mathematical problems in a wide variety of ordinary life and academic situations" [21]. Over the past thirty years, studies have shown mathematics anxiety to be a highly prevalent problem for students [19, 22-26]. Studies indicate that math anxiety is found in elementary students [27, 28], in high school students [27, 29], and in college students [30, 31]. In my experience, math anxiety is extremely prevalent in our developmental math community college students.

Math anxiety can result from environmental factors such as myths, teachers, and parents [28, 32]. Intellectual factors that affect math anxiety include learning styles, persistence, self-doubt, and dyslexia [32, 33]. Personality factors such as low self-esteem, shyness, and intimidation can also affect math-anxious students [34].

Research has shown relationships between math anxiety and achievement, between math anxiety and gender, and between math anxiety and age. A negative relationship between math anxiety and math achievement has been found across all grade levels, K-college [35, 36]. In the early grades, there is no significant difference in the math anxiety experienced in either gender [36], but females exhibit more math anxiety in secondary school and in college [37, 38]. Some studies support the belief that nontraditional-aged students exhibit more math anxiety than traditional-aged students [35, 39]. However, Bitner, Austin, and Wadlington [30] found no evidence of this trend, although they did find that nontraditional-aged students reported more anxiety in general than traditional-aged students.

Recent research suggests various ways that teachers can prevent and reduce math anxiety: designing better teaching practices [28, 40], creating a comfortable atmosphere [27, 40], providing encouragement [28, 41], using alternative assessment [28, 42], and exhibiting a better understanding of learning styles [34, 43]. Parents can also help students to curb their math anxiety [44], and students can help themselves in the effort, as well [31, 45].

College students report that they experience lower levels of anxiety in courses that are not quantitative [46]. It has been found that 27% of all college students first report feelings of math anxiety in their freshman year of college [27].

Given the fact that many students experience math anxiety in the traditional classroom; teachers should design classrooms that will make children feel more successful. Students must have a high level of success or a level of failure that they can tolerate. Therefore, incorrect responses must be handled in a positive way to encourage student participation and enhance student confidence. Studies have shown students learn best when they are active rather than passive learners [47].

TEACHING METHOD

a. Cooperative learning

Cooperative learning (CL) may be broadly defined as any classroom learning situation in which students of all levels of performance work together in structured groups toward a shared or common goal. According to Johnson, Johnson and Holubc, [48]: "Cooperative learning is the instructional use of small groups through which students work together to maximize their own and each other's learning." A review of the literature on CL shows that students benefit academically and socially from cooperative, small-group learning [49]. CL can produce positive effects on student achievement [50-56] and mathematics performance [57, 58]. The National Council of Teachers of Mathematics (NCTM) recommends that students be provided opportunities to work together cooperatively in large and small groups on difficult problems (problems that arise out of their experiences and frames of reference). Teachers have the option of structuring lessons individualistically, or cooperatively. In a traditional classroom, the teacher is the key person in the leading the lessons, learning situation, providing information, explaining concepts or skills, giving examples and paces the class.

In classrooms where collaboration is practiced, students pursue learning in groups of varying size: negotiating, initiating, planning and evaluating together. Rather than working as individuals in competition with every other individual in the classroom, students are given the responsibility of creating a learning community where all students participate in significant and meaningful ways [55]. CL requires that students

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work together to achieve goals which they could not achieve individually. The most prominent methods of CL have been developed by scholars and researchers alike [50, 53, 56].

b. E-learning

The term e-learning comprises a lot more than online learning, virtual learning, distributed learning, networked or web-based learning. E-learning is commonly referred to the intentional use of networked information and communications technology in teaching and learning. A number of other terms are also used to describe this mode of teaching and learning. They include online learning, virtual learning, distributed learning, network and web-based learning. Fundamentally, they all refer to educational processes that utilize information and communications technology to mediate asynchronous as well as synchronous learning and teaching activities. On closer scrutiny, however, it will be clear that these labels refer to slightly different educational processes and as such they cannot be used synonymously with the term e-learning.

However, it has been observed that the first generation of e-learning programs focused on presenting physical classroom-based instructional content over the internet with very little attention given to the peculiar nature of this delivery program in comparison to the tradition classroom lesson [59].

Today, e-learning is understood as a term describing an educational setting in which teaching and learning take place within an Internet-based environment [60].

c. Research Framework

The main aim of the present study is to investigate the effect and relationship between learning methods, math anxiety, WMC and mathematical performance of college students. Thus the main question addressed here is: Can learning method improves the negative effect of high math anxiety on mathematical performance? In an attempt to answer this question the following objectives were sought:

The first objective of the study was to discover whether in which group of math anxiety (low or high), students have the highest mathematical problem solving in math score based on learning methods.

The second objective was to find the coloration between math anxiety and WMC on mathematical performance.

The second objective was to find in which groups of learning method, students have lowest math anxiety.

The third objective was to find in which groups of learning method there is a significantly interaction of math anxiety and WMC no mathematical problem solving.

The fourth objective was to find in which groups of learning method with controlling math anxiety, effect of WMC is more than other groups of learning methods.

2. MATERIALS AND METHODS

a. Design, participants and procedure

Our sample was form students of Azad University of neyshaboor of Khorasan Razavi province (n = 126). For one semester, after a primary exam all Participants were divided to three groups and all of them were taught a 3 calculus chapter (limitation, diffraction, integration). The exam was taken that indicate students in three groups have no significant difference in mathematical performance. Students in 1st group studied the material cooperatively (n=42); students in the 2nd group studied the material in e-learning method (n=42) and students in 3th group studied the material in traditional learning class (n=42).

In First group, after a primary test and consultation with an expert and their teacher students were divided in 8 groups with 4 member and 2 groups with 5 members. For teaching the lessons, all principles of the CL were observed by teacher.

In second group, students in the specified period time had to download the booklets from the teacher homepage and studied by themselves and for any problem or question, could mail to the teacher or in specified time chat with him.

In third group, like a traditional class teacher was a key person for teaching students' lessons.

At the end of the each chapter all participants had to come to the university and a similar test was taken from all of them. For this purpose, random multistage stratified sampling design was used.

b. Procedures

The research instruments were:

1- Digit Span Backwards Test (DBT)

2- Mathematics Anxiety Rating Scale (MARS)

Also the average of three tests were taken at the end of the term was counted for mathematical performance. These scores were estimated from 20.

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c. Digit Span Backwards Test (DBT)

For measuring students' WMC, DBT has been showed to be the most suitable test [18, 20, 61]. To this end, the digits were read out by an expert and the students were asked to listen carefully, then turn the number over in their mind and write it down from left to right on their answer sheets. WMC was originally has seven plus or minus two storage unit as Pascual Leoni described. Students' WMC divided to two groups; Students with WMC scale less than mean at their class goes to group labeled less WMC and Students with WMC scale more than mean at their class goes to group labeled high WMC. Table 1 shows the WMC distribution.

Table1: The students' WMC distribution over the sample

Learning Method	Low	High
Traditional learning	n = 20	22
Cooperative Learning	n = 23	19
e-learning	n = 18	24

d. Mathematics Anxiety Rating Scale (MARS)

The level of anxiety was determined by the score attained on the Math Anxiety Rating Scale (MARS), which has been recently developed in the Faculty of Mathematical Sciences, Ferdowsi University of Mashhad. The MARS for this research was newly designed by the researcher according to the inventory test of Ferguson (1986). It consists of 32 items, and each item presented an anxiety arousing situation. The students decided the degree of anxiety and abstraction anxiety aroused using 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 0.93. Students' mathematics anxiety divided to two groups; Students with math anxiety scale less than mean at their class goes to group labeled less math anxiety and Students with math anxiety scale more than mean at their class goes to group labeled high math anxiety. Table 2 shows the Math anxiety distribution.

Table2: The students' Mathematics anxiety distribution over the sample

Learning Method	Low	High
Traditional learning	n = 22	20
Cooperative Learning	n = 24	18
e-learning	n = 17	25

3. RESULTS

WMC, mathematics anxiety should be correlated to mathematical problem solving according to research literature. Concern to Table.3, significant correlation between these factors and mathematical performance was obtained based on learning methods. Students' mathematical problem solving (math score) was positively correlated with WMC towards mathematics (at 0.01 levels for traditional and e-learning, at 0.05 levels for CL). According to the results correlation between mathematical performance and WMC in e-learning is more than correlation in other learning methods.

In addition the Pearson's correlation between students mathematical problem solving and mathematics anxiety was negatively significant (at 0.01 levels for traditional and e-learning, at 0.05 levels for CL). According to the results correlation between mathematical performance and mathematics anxiety in CL is less than correlation in other groups.

Table3: Correlation between mathematical performance and predictive factors based on learning methods

Learning method		mean	SD	Math Score	Working Memory Capacity	Math Anxiety
Traditional Learning	Math Score	13.37	5.81	1		
	Working Memory Capacity	4.20	129	.298**	1	
	Math Anxiety	103.62	9.98	-.252**	-.323**	1
Cooperative Learning	Math Score	17.21	3.16	1		
	Working Memory Capacity	4.44	1.09	.242*	1	
	Math Anxiety	90.59	16.14	-.200*	-.212*	1
e-learning	Math Score	11.76	7.94	1		
	Working Memory Capacity	4.03	1.31	.342**	1	
	Math Anxiety	111.23	16.77	-.304**	-.298**	1

* Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level

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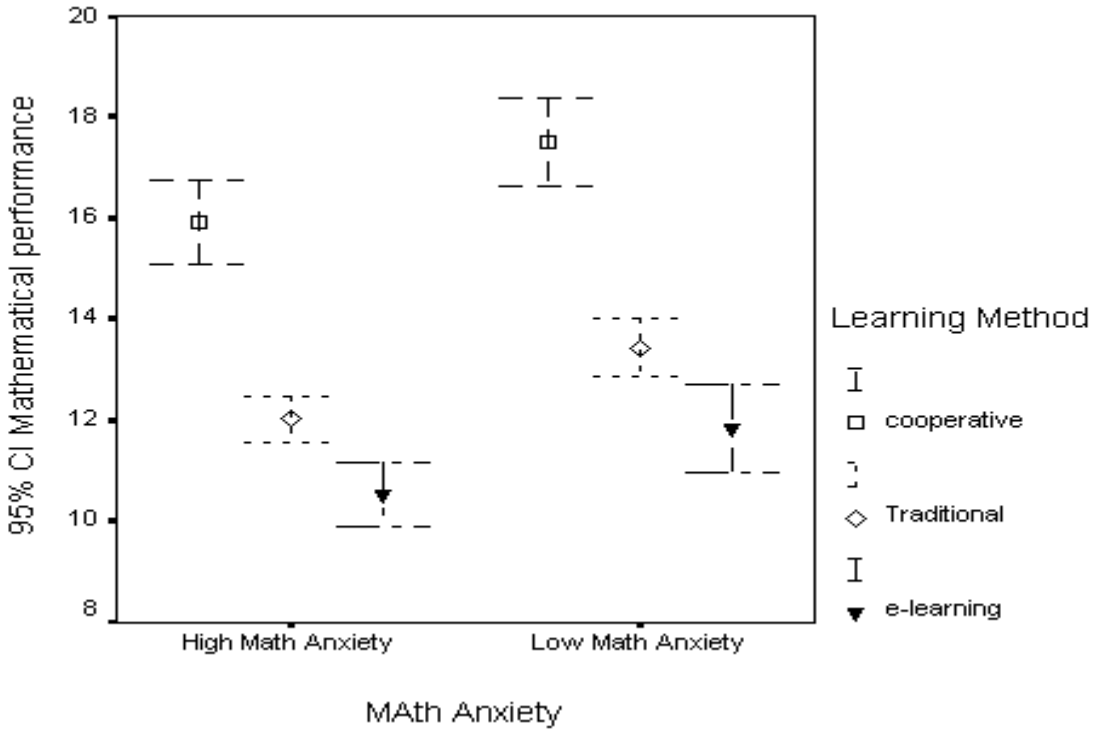
Figure 1, interprets the mathematical performance and math anxiety over the sample based on learning methods. Students studied their lesson in cooperatively groups with whether high or low math anxiety had better performance in mathematical problem solving. Moreover, students in e-learning method with high math anxiety had worst mathematical problem solving than another group of anxiety and learning methods.

Figure1: The students' Mathematics anxiety distribution over the sample based on learning methods



One way ANOVA found significant difference between students' math anxiety and Learning method (P<.01). According to the result, Students with CL method had better math anxiety than other learning methods. Moreover students with e-learning method had worst math anxiety scale.

Table4: The math anxiety means difference between learning methods

(I) Learning method	(J) Learning method	(I-J) Mean Difference	P-Value
Traditional	**Cooperative**	13.03	P<.05
Traditional	**e-learning**	7.61	P<.01
Cooperative	**e-learning**	20.64	P<.05

Univariate analysis of variance (ANOVA) indicated that the WMC and math anxiety have significantly effect on mathematical problem solving. Also There is a significantly intersection effect of WMC and math anxiety. Table 5, shows univariate analysis of variance (ANOVA) results obtained for each main effect and intersection effect of WMC and math anxiety.

In traditional class, There is significant main effect for WMC (F (1, 35) = 31.24, p< .01). There is significant main effect for math anxiety (F (1, 35) = 24.74, P<.001). There is a significant interaction effect of WMC and math anxiety (F (1, 35) = 15.32, P<.01)

In cooperated class, There is significant main effect for WMC (F (1, 38) = 11.28, P<.05). There is significant main effect for math anxiety (F (1, 38) = 10.92, P<.05). There is a significant interaction effect of WMC and math anxiety (F (1, 38) = 12.53, P<.05)

In e-learning method, There is significant main effect for WMC (F (1, 38) = 42.37, P<.001). There is

significant main effect for math anxiety (F (1, 38) = 39.41, P<.001). There is a significant interaction effect of WMC and math anxiety (F (1, 38) = 24.67, P<.001)

Table5: Effect of Predictive factor on mathematical problem solving based on learning methods

Learning method		R Squared	F	P-Value
Traditional learning	WMC	.235	31.24	
	Math anxiety		24.74	
	WMC* Math anxiety		15.32	P<.001
Cooperative learning	WMC	.172	11.28	
	Math anxiety		10.92	
	WMC* Math anxiety		12.53	P<.05
e-learning	WMC	.431	42.37	
	Math anxiety		39.41	
	WMC* Math anxiety		24.67	P<.001

Analysis of covariance (ANCOVA) showed that with controlling the effect of math anxiety on mathematical performance, WMC have significantly more effect on mathematical performance in e-leaning method than other learning methods.

In traditional class, There is significant main effect for WMC (F (1, 36) = 41.36, P<.001). There is significant main effect for math anxiety (F (1, 36) = 28.23, P<.001).

In cooperated class, There is significant main effect for WMC (F (1, 39) = 17.04, P<.05). There is significant main effect for math anxiety (F (1, 39) = 14.81, P<.05).

In e-learning method, There is significant main effect for WMC (F (1, 39) = 61.74, P<.001). There is significant main effect for math anxiety (F (1, 39) = 32.51, P<.001).

Table6: Effect of WMC on mathematical problem solving with controlling effect of math anxiety based on learning methods

Learning method		R Squared	F	P-Value
Traditional learning	WMC	.315	41.36	P<.001
	Math anxiety		28.23	P<.001
Cooperative learning	WMC	.152	17.04	P<.05
	Math anxiety		14.81	P<.05
e-learning	WMC	.531	61.74	P<.001
	Math anxiety		32.51	P<.001

4. DISCUSSIONS

According to results of this study, some psychological factors like WMC and math anxiety can predicate mathematical problem solving. Findings of this study support previous claims that these psychological factors could predict mathematical performance (e.g., [18, 20] for WMC, [18, 22, 23, 26] for math anxiety).

According to the results Math anxiety had negative correlation with mathematical performance, so with reducing the students' math anxiety maybe their performances in math problem solving get better. So finding some methods that help students to overcome their math anxiety can be beneficial. At this paper, three learning methods and their effect on students' math anxiety and mathematical performance were discussed.

This study showed that students who studied in cooperatively groups had significantly better mathematical performance in the math classes than other groups whether high or low math anxiety. This finding supports this fact that studying cooperatively could make Students' mathematical performance better than students with other learning methods. According to the result, it indicates that CL can control students' math anxiety. This happen maybe students learned their lessons actively and instated of memories everything try to understand. During the studying in the group, after

challenging to understand the new concepts in math, one of the advantages of CL could be show the students' ability to themselves, it cause that their self confidence improve and when student understand that his mistakes can be his classmates mistake it cause that his math anxiety reduce and they try to resolve their mistakes together. Moreover, students learn to use their ability and individual characteristic in the true way to had better mathematical performance for example WMC as individual characteristic.

According to the literature, mathematical performance can be predicted by some predictive factor like WMC [18, 20].

According to the results WMC had Positive correlation with mathematical performance, so Students with high WMC maybe had better performances in math problem solving. Then finding some methods that help students with low WMC have better performance in math activity can be beneficial.

Results of this study showed that with controlling the math anxiety, effect of WMC on students' mathematical performance with e-learning was more than other learning methods. It indicates that students in e-learning method maybe they couldn't understand the new concepts by themselves and memorize their lessons then the consequence is students with high WMC could had better performance in mathematical problem solving. According to the theory of zone of development proximity (ZDP) and because self study (or here e-learning) in compare with CL and traditional learning, students weren't in the class and didn't have any communication together, maybe how much students related together for learning and studying could had better performance in math problem solving.

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