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The Effect of an Intelligence Games Course on Sixth Grade Students' Mathematical Reasoning Abilities*

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Abstract

The aim of this research is to examine the effectiveness of intelligence games (IG) on mathematical reasoning abilities (MRA) and mathematics achievement scores of students. For this purpose, mathematical reasoning pre-test was given to three groups of 6th grade middle school students, and then, after the experimental group was given a training program that included all the contents of the IG course curriculum, a mathematical reasoning post-test administered in all groups. The data obtained were evaluated with SPSS 25 package program, ANOVA and ANCOVA analyses. According to the analysis, since the difference between the groups' mathematical reasoning pre-test scores was statistically meaningful, the post-test results were evaluated with ANCOVA. According to the results of the evaluation of the post-test points of the participants, the difference between the experimental group and the control 2 group was found to be statistically significant and this was interpreted as a positive development in the MRA of the students who received IG training. While there found not any significant differences between the MRA posttest points of the groups participating in the study and their genders, a significant difference was found between their math course achievement grades. This was interpreted as a meaningful affect in the math course grades the students who received IG training. Based on the study, it can be suggested that due to the important influence of IG on MRA, it may be useful to integrate them into the activities in mathematics courses conducted at school.

Keywords: Reasoning, Mathematical Reasoning, Intelligence Games.

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Introduction

In a developing and changing world, the competencies expected from individuals have also changed. Higher level competencies such as problem solving, reasoning, critical and creative thinking have gained importance. In this context, the basic aims of education have been revised. Considering these high-level abilities expected from individuals, it is actually possible to see the main purpose of mathematics education. Because mathematics education aims to develop abilities such as establishing cause and effect relationships, analysis, problem solving, prediction, creative thinking, and reasoning (Milli Eğitim Bakanlığı, 2005).

Recent developments have required learning environments to go beyond being uniform. With the constructivist approach, in which learners create information based on their past experiences (Airasian & Walsh, 1997), learning environments in which students are centered and their needs are taken into account to develop their thinking abilities have gained importance. In this way, the approach of trying to bring individuals with different characteristics, experiences and experiences to the same goals has been moved away (Koç & Demirel, 2004). In this direction, the Ministry of National Education wanted new generations to be able to not only know mathematics, but also to be able to apply what they know, solve problems and make reasoning with the new programs implemented in 2005 (MEB, 2005). In these changes, revisions were made frequently and MEB (2015) defined reasoning as a mathematical skill that students should acquire in the 5th, 6th, 7th and 8th grade curricula. Reasoning is defined as the use of available data to make decisions and reach conclusions (Nickerson, 2004). Mathematical reasoning, on the other hand, is defined as the process of obtaining new results by using mathematical tools and thinking techniques based on the data of the individual's past experiences (MEB,2013).

Mathematical reasoning is based on the individual's past experiences and thinking techniques. A review of the literature reveals that there are different classifications ofmathematical reasoning. Inductive and deductive reasoning, which are mostly considered as thinking techniques, are also described as complementary roles in mathematical reasoning (Simon, 1996). NCTM principles classify reasoning as algebraic, geometric, probabilistic and statistical based on subject matter (Lithner, 2005). Akkuş Çıkla and Duatepe (2002) categorized reasoning into three groups: algebraic, proportional, geometric and statistical based on subject matter; analytical and holistic based on perspective; and practical and abstract based on thinking style. In algebraic reasoning, predictions and assumptions are made in algebraic subjects, in proportional reasoning, in addition to the ability to perform operations, simultaneous changes and comparisons are made, while in geometric reasoning, assumptions are made about the properties of two or more dimensional objects and their location, direction and transformations (Aydoğan Yenmez & Gökçe, 2022, p.16). Statistical reasoning involves making sense of and interpreting statistical data. According to the point of view, in mathematical reasoning, the parts are examined separately in the analytic approach, while the holistic approach deals with the whole, not the parts. While abstract reasoning involves theoretical knowledge, practical reasoning involves transfer to daily life (Umay, 2003).

Lithner (2008), who has conducted long-term studies on the process of mathematical reasoning, classified the process into two groups: analogy-based and creativity-based. He categorized analogy-based mathematical reasoning as rote-based and algorithm-based. In Lithner's (2008) classification, while analogy-based mathematical reasoning involves the maintenance of a procedure, creativity-based reasoning involves in-depth reasoning. Student can use one of these types of reasoning for a situation or they can use several of them at the same time.

Kiili (2007) reveals in his study that reasoning abilities can be developed in individuals with games at an early age. In this case, it can be said that one of the importantways to create different learning environments for students, support their reasoning and enable them to develop different strategies is IG (Dicle, 2019). With IG, individuals have the opportunity to develop higher level abilities such as creative, critical and reflective thinking, decision making and problem solving. With IG, individuals find the opportunity to develop high-level abilities such as creative thinking, critical thinking, reflective thinking, decision making, and problem solving (Demirel, 2015). At this point, based on the idea that IG can be a good tool for students to raise their cognitive competence, problem solving and thinking abilities to higher levels through games and activities, MEB (2013) decided to teach them as an elective course in secondary schools as of the 2012-2013 academic year. In this framework, MEB (2013) categorized IG as shown in Table 1.

Table 1. *Classification of IG*

Game Type	Examples
Reasoning and processing games	Sudoku, action square, kendoku, apartment
Verbal games	Anagrams, cipher games, word hunt
Geometrik-mechanical games	Tangram, soma cube, katamino
Memory games	Matching, picture matching
Strategy games	Reversi, mangala, abolone
Intelligence questions	

With the inclusion of the concept of reasoning in the mathematics curriculum and the studies conducted abroad, the importance of MRA has been clearly demonstrated. On this basis, a number of studies have been conducted on MRA. Regarding IG (in some studies), the opinions of teachers and prospective teachers on IG were included (Adalar & Yüksel, 2017; Alkaş Ulusoy, Saygı & Umay, 2017; Saygı & Alkaş Ulusoy, 2019). There are also studies that reveal students' spatial abilities, problem solving abilities, problem solving strategies andreasoning abilities (Demirkaya & Masal, 2017; Dokumacı Sütçü, 2017; Kurbal, 2015).

Yöndemli and Taş (2018) conducted a study to reveal the efficacy of IG on the MRA of middle school students. When examined from the studies, in addition to the studies on teachers and prospective teachers, there are studies in which students' mathematical abilities are measured according to a selected subject area. In addition to these, it was observed that there was no study in which all the contents of the IG course were applied and the effect of this on participants' MRA was explained. Based on this deficiency, this study aims to contribute to the literature.

With this study, it was aimed to explain whether a training program that includes all of the games in the curriculum of the elective IG course has an effect on the MRA of 6th grade middle school students. Therefore, responses were sought to the following research problems;

1. Is there a statistically meaningful difference between the mathematical reasoning scale pre-test scores of the experimental group and the control group who received IG training?

2. Is there a statistically meaningful difference between the post-test scores of the mathematical reasoning scale of the experimental group and the control group who received IG training?

3. Is there a statistically meaningful difference between the post-test scores of the students in the experimental and control groups from the mathematical reasoning scale and their gender?

4. Is there a statistically meaningful difference between the post-test scores of the students in the experimental and control groups from the mathematical reasoning scale and their end-of-year mathematics course grades?

Methods

In this study, the efficacy of the application made within the scope of the IG course on the MRA of 6th grade middle school students was tested. The study was conducted using quantitative and experimental research method. Because with experimental research, the procedures performed can be compared, their effects can be examined and the results can lead the researcher to more precise conclusions (Büyüköztürk et al., 2009, p.13).

Study Model

The study was designed as a quasi-experimental design with a pre-test and a post-test control group. In the pretest-posttest design with control group, the unbiased assignment of the independent variable to the groups strengthens the design (Gliner et al., 2015, p.60). It had one experimental and two control arms. In the study, the implementation of IG content was determined as the independent variable, and the level of mathematical reasoning, gender, and mathematics course achievement grade were determined as the dependent variables. Table 2 below shows the quasi-experimental design of the study.

Table 2. *A Quasi-Experimental Design with Pre-test & Post-test Control Group*

Groups	Pre test	Experimental Procedure	Post test
Experimental Group	X	IG	X
Control Group 1	X	0	X
Control Group 2	X	0	X
IG (Intelligence Games)			

Study Group

The sample of the study includes 6th grade students who attend a secondary school in the central district of Niğde province in the 2022-2023 academic year. Convenience samplingwas used to select the study sample. The reason for choosing this sampling method is that the current situation is accessible, fast and provides convenience to the researcher (Gliner et al., 2015, p.125). One experimental group was randomly chosen from the school's 6th grade classes, one experimental group was randomly chosen from those who had taken an IG course, and two control groups were randomly chosen from the other classes. Table 3 below shows the distribution of the classes and students.

Table 3. *Distribution of Students in the Research Group*

Class	Group	Female	Male	Total
6A	Control Group 1	9	17	26
6B	Control Group 2	10	13	23
6D	Experimental Group	15	8	23

Looking at Table 3, we can see that the number of students in all classes is close to each other. All participant in the classes were entered into the study and there were no missing data.

Data Collection Tools

In order to measure students' MRA, the "Mathematical Reasoning Assessment Scale" was used in the pretest and posttest applications. The scale was developed by Çoban (2019) and includes 11 multiple-choice and 12 short-answer open-ended questions. While the first part of the scale consists of multiple-choice questions, it contains enough questions that can measure the sub-dimensions of MRA to ensure content validity. In the second part, which consists of open-ended questions, it was allowed to express how mathematical reasoning is used (Çoban, 2019). The items of the scale were analyzed and the K20 reliability coefficientwas found to be 0.81. This result shows that the data to be obtained from the scale will be well reliable.

When the scale was evaluated, the correct answers to the multiple-choice questions in the first section were given 1 point and the incorrect answers were given 0 point. Open-ended questions were evaluated with the "Progressive Scoring Scale" developed by Marzano (2000).

The validity and reliability of this scale was demonstrated by Pilten (2008). According to the Progressive Scoring Scale, open-ended questions were scored as follows:

• 0 points; the student did not make any judgment.

• 1 point; the student gave an incorrect answer, but was partially correct in his/her reasoning.

• 2 points; the student gave an incorrect answer, but was able to partially demonstrate the solution process, and although he/she was able to identify the correct reasoning, he/she could not complete it.

• 3 points; the student could not explain why his/her answer was correct and could not fully describe the logic of the generalization.

• 4 points; The student was able to completely explain the procedure and the correctness of the right solution and was able to completely express the logic of the generalization.

While the students' responses were evaluated according to the Progressive Scoring Scale, the Mathematical Reasoning Scale pre-test and post-test were evaluated by two different field experts and the reliability of the evaluation was ensured by finding 94% agreement percentage with the inter-rater percentage agreement method. The sum of the scores obtained from the first and second sections of the scale was used as Mathematical Reasoning pretest and posttest scores.

Data Collection Process

In the initial phase of the research, the Mathematical Reasoning Scale was administered to experimental and control students. Then, the experimental group was taught and played at least one game from all game types in line with the study plan prepared in accordance with the IG curriculum. Before the implementation, the study plan was examined by two field experts and an academician and found appropriate. Table 4 below shows the study schedule prepared.

Table 4. *Working Schedule*

Week 1	Lesson 1	Sudoku teaching.
	Lesson 2	Sudoku solution.
Week 2	Lesson 1	Sudoku solution.
	Lesson 2	Intelligence questions solution.
Week 3	Lesson 1	Anagrams teaching.
	Lesson 2	Anagrams solution.
Week 4	Lesson 1	Tangram teaching.
	Lesson 2	Tangram solution.
Week 5	Lesson 1	Tangram solution
	Lesson 2	Intelligence questions solution..
Week 6	Lesson 1	Picture matching.
	Lesson 2	Picture matching.
Week 7	Lesson 1	Reverse teaching.
	Lesson 2	Reverse playing.
Week 8	Lesson 1	Mangala teaching.
	Lesson 2	Mangala playing.

Within the framework of the plan shown in Table 4, these games were played by the researcher for 2 class hours each week and the participation of the students was ensured. The games and types of games applied to the students are given below; (1) Sudoku, (2) Anagrams, (3) Tangram, (4) Picture Matching, (5) Reversi and Mangala, (6) Intelligence Ouestions.

In line with the prepared work schedule, introductory cards, game instructions and worksheets were prepared for each game. Figures 1, 2 and 3 below show some of the introductory cards, instructions and worksheets for the tangram game.

Figure 1. Tangram Introduction Card

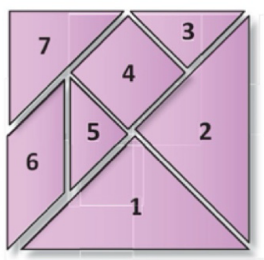
TANGRAM

A simple tangram consists of 7 pieces. Tangram pieces can be used to create geometric shapes, objects, human or animal figures, alphabetic letters or numbers.

Objective: To try to create the given shape using all 7 pieces in the tangram.

Rules:

- The desired shape is achieved with the fewest moves and in the shortest time.

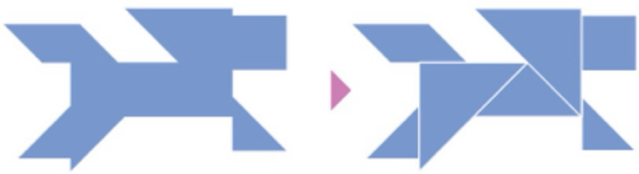


When Figure 1 is examined, the students were initially given a 7-piece tangram and given the necessary information about the game.

Figure 2. Tangram Instruction Sheet

TANGRAM INSTRUCTIONS

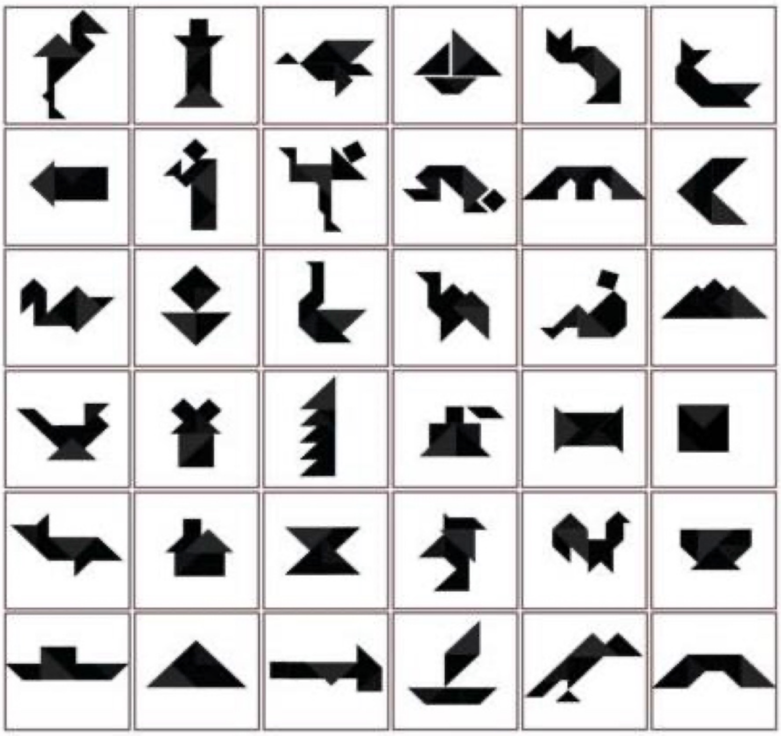
1) Divide the students into groups.
2) Give each group a tangram.
3) First of all, make sure that the pieces of the tangrams you use are colored.
4) Ask the students to examine the tangram pieces.
5) Ask the students, do any two pieces in the shape of a triangular region combine to form a quadrilateral region? Can some of the pieces be put together to form a rectangular region? How many different models of polygonal regions are there? Ask questions that will encourage them to think.
6) Then ask them to do it using a dog figure.



7) Divide the class into groups. Open a tangram shape on the board. Check the groups as they work.

Looking at Figure 2, steps are given to guide the practitioner while playing the tangram game.

Figure 3. Tangram Worksheet



The visuals in Figure 3 were presented to the students one by one and they were expected to form the shapes. Then, they were shown the colored versions of the same pictures and were asked to compare their answers.

Data Analysis

The data obtained from the mathematical reasoning scale used in the research were processed using the SPSS 25 software. No data with missing values were found during the analysis process. Then, it was controlled if the pretest and posttest scores in the experimental and control groups showed normality or not. Levene's test was also performed for the homogeneity assumption. As a result of the analysis, the normality of the variances was determined as S<1.5 with the Skewness-Kurtosis test. According to the test result, a value between -1.5 and +1.5 is seen as evidence of a normal distribution (Tabachnick & Fidell, 2013).

- One-way ANOVA, one of the parametric tests, was applied to explain whether the pretest scores on the mathematical reasoning scale showed a statistically meaningfuldifference according to groups since the conditions were met. One way ANOVA is preferred in intergroup measurements where an independent variable with two or more levels is used (Gliner et al., 2015, p.292).

- ANCOVA was used to examine whether there was a statistically meaningful difference in posttest scores on the mathematical reasoning scale by group. In this way, it was aimed to keep the pretest scores under control. In the analysis of covariance, the posttest scores are adjusted for the differences in the groups' pretest scores, making the posttest scores a single variable (Gliner et al., 2015, p.328). The logic here is that there may be differences between the groups even if there is no bias before the experimental application. In addition, Bonferroni technique was used in order to reveal pairwise comparisons while applying ANCOVA.

- One Way ANOVA was conducted to explain the statistical relationship between students' gender and mathematical reasoning scale posttest scores. As a result of the. analysis performed to meet the prerequisites, it was seen that the variances were homogeneous (F=.88, p>.05) and normally distributed.

- One Way ANOVA was conducted to explain the statistical relationship between students' end-of-year mathematics course achievement grades and mathematical reasoning scale posttest scores. As a result of the analysis performed to meet the prerequisites, it was seen that the variances were homogeneous (F=1.516, p>.05) and normally distributed.

Findings

This chapter presents the findings of the research questions by analyzing the data obtained from the mathematical reasoning scale.

Findings Regarding the First Sub-Problem

The pre-test scores of the students in the experimental group and the Control 1 and Control 2 groups were determined with the mathematical reasoning scale before the educational program prepared within the scope of the IG course was implemented. One-way ANOVA was applied to analyze the data to see if there were any statistically meaningful differences between the pretest scores.

From the descriptive analysis, the highest mean (X=16.65; SD=6.29) belongs to the experiment group. The lowest mean (X=11,86; SD=5,37) belongs to the Control 2 group. The mean of the Control 1 group (X =12,76; SD=5,37) is the second highest mean. As a result, the data were analyzed with One Way ANOVA. Analysis results are as in table 5;

Table 5. *Adjusted Means of the Groups' Posttest Scores*

Groups	N	Mean	Adjusted Mean
Exprimental Group	23	20,00	18,01
Control Group1	26	13,69	14,34
Control Group 2	23	10,13	11,38
Total	**72**		

Table 5 indicates that a statistically meaningful difference existed between the pretest scores of the experimental group and the Control 1 and Control 2 groups (F=3,484; p=0.036<0.05). Post hoc analysis was performed to determine the cause of the differentresults, and it was found to be in favor of the experimental group. Posttest scores were analyzed using ANCOVA to determine the effect of this statistically meaningful difference in pretest scores on posttest scores after the experimental study.

Findings Related to the Second Sub-Problem

Posttest means of the Mathematical Reasoning Scale for experimental, control 1, and control 2 groups and adjusted group means as a result of ANCOVA analysis are shown in Table 6:

Table 6. *Adjusted Means of the Groups' Posttest Scores*

Groups	N	Mean	Adjusted Mean
Exprimental Group	23	20,00	18,01
Control Group1	26	13,69	14,34
Control Group 2	23	10,13	11,38
Total	**72**		

When analyzing the sixth table, the normal averages of the experimental groups were 20,00 and the adjusted averages were 18,01. Whereas the normal averages for group 1 were 13.69, the adjusted averages were 14.34, and whereas the normal averages for group 2 were 10.13, the adjusted averages were 11.38. Although the adjusted averages of the control groups increased compared to their normal averages, it is a low average compared to the experimental group.

Bonferroni's test within ANCOVA analysis was used to determine statistical significance of difference between groups on mathematics reasoning scale, experiment and control 1 and control 2. The Bonferroni test result and the difference between the post-test points of the groups are shown in Table 7:

Table 7. *ANCOVA Results of the Groups' Posttest Scores*

Grup	Groups	Mean Difference	Std. Error	p
Exprimental	Control 1	3,67	1,56	.06
	Control 2	6,62*	1,63	.00
Control 1	Exprimental	-3,67	1,56	.06
	Control 2	2,95	1,52	.17
Control 2	Exprimental	-6,62*	1,63	.00
	Control 1	-2,95	1,52	.17

When the analysis of covariance results in Table 7 are analyzed according to the post- test scores corrected according to the pre-test scores, a statistically meaningful difference was seen between the experimental group and the Control 2 group (F(2-68)=8.23; p=.00). That is, after ANCOVA analysis, the common effect showed a statistically meaningful difference among the students in the experimental group using the IG program.

Findings Related to the Third Sub-Problem

One-way ANOVA was used to determine whether the posttest scores on the mathematical reasoning scale were statistically meaningful differences between the students in the experimental group and the Control 1 and Control 2 groups, as well as the gender of the students.

According to the described analysis, the mean posttest values of the girls (X=15.76, SD=7.45) were higher than the mean values of the boys (X=13.50, SD=8.23) and the findingsare presented in Table 8:

Table 8. *One-Way Variance Analysis of Mathematical Reasoning Post-test Scores by Gender*

	Sum of Square	sd.	Mean Square	F	p
Between Groups	92,035	1	92,035	1,483	.22
Within Groups	4343,618	70	62,052		
Total	4435,653	71			
(p>.05)					

(1=experiment group, 2=control 1 group, 3=control 2 group)

According to the analysis, there was no statistically significant differ by gender between the Mathematical Reasoning Scale posttest scores of the students participating in the study (F=1.483, p>.05).

Findings Related to the Fourth Sub-Problem

Following the study, which was conducted in accordance with the study plan, a one-way analysis of variance was used to determine if there was a statistically meaningful difference between the post-test scores of all students in the groups and the end-of-semester grades in the school mathematics course, and the findings are presented in Table 9:

Table 9. *One-Way Variance Analysis of Mathematical Reasoning Post-test Scores and Mathematics Achievement Grades*

	Sum of Square	sd.	Mean Square	F	p	Difference
Between Groups	21344,046	26	820,925	5,004	.00	1>2
						1>3
Within Groups	7382,274	45	164,051			
Total	28726,319	71				
(p<.05)						

(1=experiment group, 2=control 1 group, 3=control 2 group)

Table 9 indicates that the distance between the Mathematical Reasoning Scale posttest scores of the participants in the study and their grades in the mathematics course was statistically significant (F=5.004, p<.05).

Discussion, Conclusion and Suggestions

The purpose of the study was to determine the effectiveness of IG on MRA and mathematics achievement of 6th grade middle school students. It is stated that students' learning through games in the classroom environment and having in-class interaction and discussion environments positively affect the development of MRA (Schliemann & Carraher, 2002). In fact, IG provide important opportunities for students to encounter, use and interact with different reasoning abilities. In this regard, the intelligence game training was applied to the students who participated in the research according to the prepared program and the results were evaluated. The analysis revealed that there was a statistically meaningful difference between the post-test values of the participants in the experimental group and the post-test values of the participants in the control 2 group. This can be interpreted as an improvement in the MRA for students taking the IG course. According to Vygotsky (1978), while children's interaction with their peers improves their reasoning processes, in such environments, individuals will have the chance to be influenced by each other's reasoning styles (Maher & Davis, 1995), and studies revealing that providing environments where students can put forward, explain and discuss their ideas enables them to develop their reasoning abilities (Altıparmak & Öziş, 2005; Steen, 1999) also support the result of the development of MRA in students taking IG lessons. Similarly, there are studies showing that students' interaction and being aware of each other's reasoning positively affect their reasoning abilities (Yankelewitz, 2009; Zembat, 2008). The mathematical reasoning posttest results of the students in the study did not show a statistically meaningful difference by gender. On the contrary, in some studies where students' MRA were measured, significant differences were found in favor of female students (Demir, 2019; Karaduman, 2018). These studies were related to proportional reasoning, one of the types of mathematical reasoning, and as a consequence it was suggested that applications could be made that might attract the attention of male students more. Similarly, in our study, IG that can attract more attention of male students can be selected. The final finding of our research is that the post-test scores on the MRA of the students who enrolled in the study were statistically different from their grades in the math course in school. In other words, students with high mathematical reasoning post-test scores also have high achievement grades in mathematics courses. In parallel with this result, Demirel (2015) investigated the efficacy of IG in students' achievement in mathematics and Turkish lessons and found that there was a significantly improved student achievement. In fact, it can be said that IG have a beneficial influence on students' math performance in school by improving their problem-solving and MRA.

Similarly, there are also studies showing that the IG course has a benefical and significant influence on students' problem solving, mathematical reasoning and positive attitudes towards mathematics (Demirel, 2015; Demirel & Yılmaz, 2016; Demirkaya & Masal, 2017; Kurbal,2015; Reiter et al., 2014; Saygı & Alkaş Ulusoy, 2019; Sargın & Taşdemir, 2020; Yöndemli, 2018; Zeybek & Saygı, 2018).

Based on these results, presenting IG as activities in the mathematics curriculum and ensuring active participation of students will contribute to the development of MRA. In addition, the IG course can be removed from being an elective course and can be conducted by experts in parallel with the mathematics course.

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