Anatolian Turkish Journal of Education

Year: 2025 Volume: 7 Issue: 2 pp. 358-380

ISSN: 2687-5314
DOI: https://doi.org/0000/ated/00.00.00

www.anadoluturkegitim.com/en
Article Type: Research Article

Recieved: 14 Aug 2025 Accepted: 29 Oct 2025

Mathematical Creativity and Achievement of Middle School Students: The Role of Parental Education and Income Levels

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Abstract

Mathematical creativity is the ability to produce new and original mathematical work. It involves students' ability to develop new ideas using acceptable mathematical patterns and models. It also includes their ability to find original solutions, apply principles in different contexts, and develop multiple solution strategies. The primary purpose of this study is to examine the mathematical creativity and mathematical achievement of middle school students. The examination will be in terms of individual factors such as gender and grade level, and environmental factors such as family education and economic status. The study, which uses correlational research design, a quantitative research method, comprised 5th, 6th, 7th, and 8th-grade students (209 boys, 189 girls) selected using cluster sampling from three schools with different socio-economic levels in the Eastern Anatolia Region. Data were collected using the Mathematical Productivity Test and Achievement Tests. Correlation Analysis and Independent Samples, Single Factor Multivariate Analysis of Variance (MANOVA) were used in data analysis. The study revealed a positive, moderately significant relationship between students' mathematical creativity and achievement. Female students' mathematical creativity levels were found to be significantly higher than male students', although the effect size of this difference was low. In contrast, no significant gender difference was found in terms of mathematical achievement. It was determined that grade level did not affect mathematical creativity, but fifth-grade students' mathematical achievement was significantly higher than that of other grade levels. Finally, it was concluded that as both the educational and economic levels of a family increase, students' mathematical creativity and achievement also increase significantly. Supportive educational practices are recommended for students from low-socioeconomic families, encouraging them to take responsibility for their learning, generate innovative solutions, and develop their mathematical creativity skills.

Keywords: Mathematical creativity, Mathematical achievement, Middle school students, Grade level

Introduction

Creativity has been conceptualized in different dimensions. Runco and Jaeger (2012) emphasize the cognitive aspect of creativity, namely the ability to generate new and valuable ideas, while the OECD (2020) views creativity as a socio-economic driving force that fuels innovation and prosperity. Similarly, Bobirca and Draghici (2011) view creativity as an engine of sustainable economic growth and social progress, while Amanah and Inganah (2025) highlight its educational and developmental dimension in shaping learning outcomes.

These different perspectives demonstrate that creativity is not merely an individual cognitive trait, but rather a multidimensional competency with educational, economic, and social implications. In this context, the Turkish Century Education Model (TCEM) aligns with this global understanding of creativity by highlighting innovation, responsibility, and learner autonomy as core competencies (MEB, 2024c).

While the importance of creativity is recognized by many individuals and societies (Liu et al., 2018; Suherman & Vidákovich, 2022; Wang & Chang, 2022), despite considerable scholarly attention, there is still no consensus in the literature regarding the precise definition of this concept (Davies et al., 2013; Sebastian & Huang, 2016). For example, while artists define creativity as the ability to produce original and aesthetically pleasing products, scientists define it as the ability to develop processes that are both useful and adaptable and to think independently and unconventionally (Guilford, 1977; Sternberg & Lubart, 1996). These differences stem from discipline-specific approaches to creativity rather than general theories of creativity (Leikin & Sriraman, 2022; Runco, 2004; Sternberg & Lubart, 1995). These discipline-based approaches have made significant contributions to the deeper and more contextual examination of creativity within specific disciplines. In this context, one type of discipline-specific creativity is mathematical creativity (Leikin & Pitta-Pantazi, 2013; Meier et al., 2021).

Mathematical creativity, on the other hand, is defined as the ability to produce new and original work specific to mathematics (Sriraman, 2005), students' ability to develop new ideas using acceptable mathematical patterns and models (Bicer, 2021), and the ability to find original solutions to mathematical problems, apply mathematical principles in different contexts, and develop multiple strategies for solution (Hadar & Tirosh, 2019; Haylock, 1987; Sriraman, 2004). This skill can be considered a tool that not only enhances mathematical achievement but also enhances students' problem-solving abilities in their daily lives (Bahar & Maker, 2011; Starko, 2022). As Robinson (2006) stated, mathematical creativity develops by experimenting, making mistakes, and learning from these mistakes. However, in most educational systems worldwide, creativity is suppressed rather than encouraged because experimentation or making mistakes is viewed as an undesirable and negative outcome (Boaler, 2022). Furthermore, creativity is often overlooked due to its complex nature in the educational process.

The factors that influence mathematical creativity can be grouped under three headings: "Individual," including factors such as student gender, achievement, perception, and readiness level; "Environmental," including factors such as parental education and socio-economic status; and "Educational," including factors including as the educational environment, pedagogical approaches, and curriculum. Although these factors are grouped in this way, they are closely interconnected. For example, There is an association between socio-economic status and success (Cabra & Guerrero, 2022; Marks & Pokropek, 2019; Reardon, 2011), between parental education and creativity (Acar et al., 2022; Mönkediek & Diewald, 2022; Pugsley & Acar, 2018), and between pedagogical approaches and success (Regier & Savic, 2020; Suherman & Vidákovich, 2024a; Thiyagu, 2014). Individuals with higher socioeconomic status have higher mathematical creative thinking skills due to their access to more educational opportunities (Acar et al., 2022).

A review of the literature on mathematical creativity is examined, it is seen that in the early years, studies on mathematical creativity generally focused on gifted individuals (Sriraman, 2003). Almost all of these studies first established a positive relationship between giftedness and mathematical creativity (Pativisan & Niess, 2008). These studies then focused on topics such as the mathematical creativity characteristics of gifted individuals, the measurement of mathematical creativity skills, and the development of mathematical creativity scales for gifted individuals (Akgül, 2014; Balka, 1974; Torrance, 1962). In later years, it was emphasized that every individual or student has mathematical creativity skills and that this skill should be developed (Grajzel., 2023; Kozlowski & Si, 2019). Previous research has concentrated primarily on the mathematical creativity skills and mathematical achievement of university and general high school students (Becerra & Regalado, 2024; Fortes & Andrade, 2019). These studies have primarily focused on the relationship between the concept of mathematical creativity and mathematical achievement (Cihlář et al., 2020; Wang, 2008; Wang & Chen, 2025). Subsequent studies have examined this relationship in terms of the effects of specific teaching approaches (mathematical creativity approach), country-level differences (PISA), additional factors in gifted students (such as mathematical metacognition and self-efficacy), and the mediating roles of creativity in other areas on mathematical creativity and achievement (Abdul Hamid & Kamarudin, 2021; Akgül & Kahveci, 2017; Liu et al., 2022; Sebastian & Huang, 2016; Singh, 2015).

Recently, growing attention has been given to mathematical creativity has been emphasized not only at higher education levels, such as university and high school, but also at middle and even primary school levels (Schindler & Lilienthal, 2020). In parallel with this, the concepts of mathematical creativity and success have begun to be included in primary and secondary school curricula in Turkey, as well as around the world (Al Moray, 2024; Kıymaz, 2009; MEB, 2018, 2024c). As a result, studies on mathematical creativity and success have begun at the secondary school level (Bal Sezerel, 2019; Bicer et al., 2024). For instance, Osakwe et al. (2022) stated that the use of problem-solving tasks with multiple solutions plays an important role in developing students' creative thinking abilities and mathematical creativity. However, gender is not a determining factor in this process. However, studies by Aydağ (2021) and Alçı Aydoğan (2025) found a weak and a positive association between mathematical creativity and academic achievement. They also stated that students' mathematical creativity levels were higher in the 8th grade than in the 7th grade. Finally, studies by Ibrahim Khalil, Prahmana (2024), and Plucker (2022) suggested that teaching methods and in-class activities should be designed to support students' creative thinking abilities and mathematical creativity.

Although previous studies have provided valuable insights into the relationship between mathematical creativity and achievement, most studies have focused on gifted or high school students. Middle school, where creativity potential is still developing, has been largely overlooked. Furthermore, these studies generally examine individual and environmental variables separately and do not investigate the interaction between these dimensions. Given that the TCEM (MEB, 2024c) framework in Turkey prioritizes creativity and learner autonomy at all levels, understanding the combined effects of individual factors (e.g., gender, grade level) and environmental factors (e.g., parental education, family income) on students' mathematical creativity and achievement have become a current necessity. Examining these relationships at the middle school level will provide significant evidence for the development of curricula and the more equitable and inclusive dissemination of creative learning opportunities. This study was designed to systematically examine the effects of the specified variables on students' mathematical creativity and mathematics achievement in order to fill this research gap.

This study aims to investigate both the mathematical creativity and achievement of middle school students in terms of individual factors like grade level and gender, and environmental factors like family education and economic status. To this end, the following sub-problems were addressed.

1. Is there a relationship between students' mathematical creativity and achievement

2. Do students' mathematical creativity and achievement differ by gender?

3. Do students' mathematical creativity and achievement differ by grade level?

4. Do students' mathematical creativity and achievement differ by family education level?

5. Do students' mathematical creativity and achievement differ by family economic status?

Method

Research Design

This study, focusing on determining middle school students' creativity and mathematical creativity, used the correlational research design, a type of quantitative method. Correlational research generally intends to examine whether and to what extent a relationship exists among two or more variables (Gay, 1987; Creswell, 2005). The correlational research design was chosen because the study aimed to reveal differences in students' mathematical creativity and achievement across socio-economic and class levels, as well as the relationship between these two variables. The primary reason for examining class-level differences is that general and mathematical creativity are not fixed traits but rather skills that can be learned and developed (Leikin, 2009). This study was conducted by ethical compliance requirements by the decision of the Erzincan Binali Yıldırım University Human Research Ethics Committee of Educational Sciences, dated February 29, 2024, Protocol No. 05/12, and a research permit from the Ministry of National Education, Ministry of National Education, numbered MEB.TT.2024.000591. This article is derived from the doctoral dissertation titled “Examination of Middle School Students’ Creativity and Mathematical Creativity Skills.”

Sample

The study sample consisted of 398 students in the fifth, sixth, seventh, and eighth grades (209 boys and 189 girls) enrolled in three public schools of low, medium, and high socio-economic status located in the center of a large province in the Eastern Anatolia Region. These students were selected using the cluster sampling method. Cluster sampling is a sampling method that divides a population into groups that share similar characteristics but are organized into distinct clusters. In this method, each cluster represents a small representative of the population, and the sample is created by randomly or systematically selecting participants from one or more of these clusters (Creswell & Creswell, 2017). The cluster sampling method was chosen in this study because, firstly, socio-economic status directly affects creativity and success (Sugiyono, 2016), and the aim was to select participants based on socio-economic status. Secondly, the socio-economic status of the population in question was to reflect the sample in the sample. Accordingly, the middle schools in the provincial center where the study was conducted were first divided into three categories: low, middle, and high middle schools, based on the socio-economic status of their surroundings. Then, one middle school was randomly selected from each category, and one section from each grade level (5th, 6th, 7th, and eighth) was randomly selected from these middle schools. However, the number of students in the low-socioeconomic middle schools was less than the number of students in the high-socioeconomic middle schools. Because families enroll their children in the high-socioeconomic middle schools, the class sizes in these middle schools are significantly larger than in other middle schools. For example, the maximum class size in low-socioeconomic middle schools is 15 students, while in high-socioeconomic schools, it is 46. Therefore, two sections from each grade level were selected from the low-socioeconomic middle schools. The distribution of students by grade level, gender, and the socio-economic status of the school is shown in table 1.

Table 1

Class and gender distribution by socio-economic level

	Grade Level								
Socio-Economic Level	5		6		7		8		
	G	B	G	B	G	B	G	B	Grand Total

Low	19	9	13	19	6	15	16	18	115
Medium	16	20	20	19	15	12	17	16	135
High	11	19	21	20	18	23	17	19	148
Total	46	48	54	58	39	50	50	53	398

According to table 1, almost all distributions are similar in terms of grade, gender, and socioeconomic status, except for the distributions of 7th-grade low-SES girls and 5th-grade low-SES boys.

According to socioeconomic status and grade, the students' past experiences of creativity and mathematical creativity were determined. For this purpose, the students' engagement in activities such as art and music, mind games, projects, and problem-solving was determined and is shown in table 2.

Table 2

Distribution of socio-economic level according to students' experiences

Question Type	Grade Level											
	5			6			7			8		
	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
Art and Music	2	10	2	6	6	19	-	12	12	1	9	12
Brain Games	1	5	20	2	3	20	-	2	9	-	3	10
Project Making	-	6	1	-	2	1	-	6	6	-	2	-
Problem Solving	-	8	9	-	4	10	-	6	10	-	12	10
Total	3	29	32	8	15	50	0	26	37	1	26	32

According to table 2, 12 (5%) of the students who had previously engaged in activities related to creativity and mathematical creativity came from low socio-economic status, 87 (35%) from middle socio-economic status, and 151 (60%) from high socio-economic status.

Data Collection Tools

Data for the study were collected using the "Mathematical Productivity Test" and "Achievement Tests." These tests are explained in detail below.

Mathematical Productivity Test (MPT)

The MPT is a mathematical creativity test. It was developed by Bal Sezerel (2019) to determine the mathematical creativity levels of students in the fifth to eighth grades. The MPT consists of three different sections: problem posing, hypothesizing, and proof. Each section includes two open-ended problems. Based on students' answers to these problems, scores for the sub-factors of mathematical creativity—fluency, flexibility, and originality—are calculated, and overall mathematical creativity scores are calculated from these factors. The lowest overall mathematical creativity score a student can receive on the MPT is zero. In contrast, the highest score can vary depending on the student's response to the subfactors of fluency, flexibility, and originality. A high score indicates high creativity, while a low score indicates low creativity. While the calculated internal consistency coefficient (Cronbach's alpha) of the scale was .852, it was found to be .895 in this study. This value indicates that the scale has a high level of internal consistency within the scope of this study and can be used as a reliable measurement tool. The MPT was used because it was appropriate for the purpose and sample of this study. The MPT was administered to the participants, and they were asked to solve the MPT questions during one class period. Students who needed additional time were given an additional five minutes. Students were asked to answer the MPT questions individually, preventing them from influencing each other. Mathematical creativity scores were calculated for each student based on their MPT responses. Each student's scores for fluency, flexibility, and creativity were evaluated by the researcher according to the scoring key. This scoring method was then reviewed with a field expert, who concluded that the method was appropriate. The researcher then re-examined the students' responses according to the scoring key. The cohesion rate between the two scores was calculated as 95%. This rate indicates high inter-rater reliability and consistency in scoring.

Achievement Test

An achievement test was prepared for each grade level. First, the researcher and an expert selected 30 questions appropriate for each grade level from those prepared for middle school students by the Ministry of National Education's General Directorate of Measurement and Evaluation (MEB, 2024a, 2024b). These questions were selected because they were valid and reliable, aligned with the Ministry of National Education's objectives. Expert teachers then reviewed the questions in these tests, and each question was checked for appropriateness to the grade level and the TCEM learning outcomes for fifth grade, and for the program outcomes for other grades. Pilot studies were conducted by administering all 20-question achievement tests, each based on grade level, to randomly selected classes. At the end of the pilot study, no changes were needed to the achievement tests. Accordingly, valid and reliable achievement tests consisting of 20 questions were created and used for each grade level. The difficulty indices of the tests ranged from .32 to .66, and the discrimination indices ranged from .54 to .68, indicating that the tests were adequate in terms of both difficulty and discrimination (Crocker & Algina, 2008). Five points were assigned to each correct answer in these tests, and the student was expected to receive a maximum of 100 points in total. A higher score indicates higher mathematical achievement, while a lower score indicates lower mathematical achievement. Students in each grade were given an achievement test based on their grade level and were asked to complete 20 questions during one class period. Students were asked to answer the questions individually, preventing them from influencing each other. Achievement scores were calculated for each student based on their correct answers. Demographic information, including name, grade, gender, parents' education level, and family average monthly income, was included in the achievement tests. Students were asked to complete these before beginning the achievement test.

Data Analysis

The MPT was used to determine students' mathematical creativity levels. Overall mathematical creativity scores were calculated for each student. Furthermore, a mathematics achievement score out of 100 was obtained for each student from achievement tests. For each student, gender was coded as Female = 1, Male = 2, family education level as Primary and middle school = 1, high school = 2, university and above = 3, and family economic level as Low (L) = 1, Medium(M) = 2, High(H) = 3, and Very High(VH) = 4. When determining the family's education level, the higher education level of the mother or father was taken into account. This assessment was conducted across three categories: Middle school (MS), High school(HS), and University(U) and above. The family's economic level was classified into four categories based on the minimum wage (approximately 22,000 TL) from The Republic of Türkiye Ministry of Labour and Social Security (T.C. Çalışma ve Sosyal Güvenlik Bakanlığı, 2025) : 0-22,000 TL was coded as low, 22,001-44,000 TL as medium, 44,001-66,000 TL as high, and 66,001 TL and above as very high. First, normality analysis was conducted. According to the normality analysis, there was no missing data and outliers for mathematical creativity and mathematical achievement scores. As a result of this normality analysis, skewness (.041, SE=.122) and kurtosis (-.394, SE=.244) were calculated for mathematical creativity scores, and skewness

(.178, SE=.122) and kurtosis (-1.026, SE=.244) were calculated for mathematical achievement scores. Since all these skewness and kurtosis values are between -2 and +2, it can be said that they are normal (George & Mallery, 2019). Secondly, Pearson correlation analysis was used to examine the relationships between the dependent variables, mathematical creativity scores and mathematical achievement scores. The analysis showed that there was a linear, positive and moderately significant relationship between students' mathematical creativity and achievement ($r(398) = .430$, $p < .001$). Due to the detection of significant correlations between the dependent variables, Single Factor Multivariate Analysis of Variance (MANOVA) in Independent Samples was preferred in comparisons between groups. Before performing the MANOVA analyses, basic assumptions were checked. Homogeneity of variances was examined with the Levene test, and equality of covariance matrices was examined with the Box's M test, and the results are presented in the findings section. According to the Levene test results, Single Factor Analysis of Variance (ANOVA) in Independent Samples was applied in cases where the assumption of homogeneity of variance was met, and the Scheffe post hoc test was used to determine the differences between groups. In cases where the assumption of homogeneity of variance was not met, the Welch test was applied, and the Dunnett C post hoc test was preferred for pairwise comparisons. In cases where the assumption of equality of covariance matrices was not met in the Box M test results, the Pillai's Trace test statistic, which is more robust to this assumption, was used. Eta squared (η^2) values were calculated to assess effect size in the analyses. The significance level was set at 0.05 in all statistical analyses. All these analyses were conducted using SPSS 27 (Statistical Package for the Social Sciences) software.

Findings

A Simple Correlation Analysis was conducted for the first sub-question, "Is there a relationship between students' mathematical creativity and achievement?" Based on this result, a single- or multi-factor MANOVA test will be used to examine students' mathematical creativity and achievement for the various factors in the study that follow. The MANOVA test was chosen because the Simple Correlation Analysis revealed a moderate relationship between students' mathematical creativity and achievement (Tabachnick & Fidell, 2013).

The MANOVA test was used to test whether mathematical creativity and achievement differed according to demographic factors such as gender, class, and family education and economic level. Levene's tests were used to determine whether variances were equal for the factors preceding the ANOVA tests in this test, and the results are presented in table 3.

Table 3

Levene Test Results

Factors	Dependent Variable	Levene Statistics	df1	df2	P
Gender	Mathematical Creativity	.142	1	396	.707
	Success	.151	1	396	.698
Grade Level	Mathematical Creativity	.233	3	394	.873
	Success	13.94	3	394	.000
Family Education Level	Mathematical Creativity	.134	2	395	.875
	Success	7.30	2	395	.001
Family Economic Level	Mathematical Creativity	.115	3	394	.951
	Success	7.63	3	394	.000

According to table 3, mathematical creativity variances were found to be significantly equal across factors such as gender, grade level, family education level, and family economic level, as well as achievement variances by gender ($p>0.05$). For these factors, a single-factor ANOVA was performed in independent samples. If any differences were found, the Scheffe test, a post hoc test used when variances are equal, was employed to identify the source of the differences. Conversely, achievement variances were found to be significantly unequal across factors such as grade level, family education level, and family economic level ($p<0.05$). For these factors, a single-factor ANOVA was performed in independent samples, along with a Welch test. If any significant differences were found, the Dunnett C test, a post hoc test used when variances are not equal, was employed to identify the source of the differences.

A single-factor MANOVA was performed to determine whether students' mathematical creativity and achievement differed by gender. Before this analysis, Box's M Test was performed for the consistency of covariance matrices. According to the results of this test, it was seen that the covariance matrices were significantly equal ($M=.461$, $F(3, 41574879.603)=.153$, $p>.05$). Results of the single-factor MANOVA indicated a significant gender-based difference in mathematical creativity and achievement (Wilks' Lambda .981, $F(2, 395)=3.878$, $p<.05$). The descriptive statistics result of the single-factor ANOVA Test performed in independent samples to determine the source of this difference is given in table 4. The inferential statistics result is given in table 5.

Table 4

Descriptive results regarding students' mathematical creativity and achievement by gender

Dependent Variable	Gender	N	$\bar{x}$	SD	SE
Mathematical Creativity	Girl	189	8.23	3.85	0.28
	Boy	209	7.29	3.86	0.27
Success	Girl	189	52.22	23.5	1.71
	Boy	209	52.63	23.55	1.63

According to table 4, the mean score of girls in mathematical creativity ($\bar{x}$ = 8.23, SD = 3.85) is higher than that of boys, while the mean score of boys in achievement ($\bar{x}$ = 52.63, SD = 23.55) is higher than that of girls.

Table 5

ANOVA results regarding students' mathematical creativity and achievement by gender

Dependent Variable	Source of Variance	SS	df	MS	F	p	η^2	Source of Difference
Mathematical Creativity	Between Groups	87.81	1	87.81	5.912	.015	0.015	G-B
	Within Groups (Error)	588.03	396	14.85				
	Total	5969.84	397					
Success	Between Groups	16.63	1	16.63	.030	.862		
	Within Groups (Error)	219169.30	396	553.46				
	Total	219185.93	397					

According to table 5, a significant difference existed between the mathematical creativity of male and female students ($F(1, 396) = 5.91$, $p<0.05$, $\eta^2=0.015$), there was no statistically significant difference between their achievement ($F(1, 396) = .030$, $p>0.05$). This result indicates that gender has a negligible effect on mathematical creativity, explaining only 1.5% of the total variance.

Finally, a post-hoc test, the Scheffe Test, was used to determine the source of the difference by gender. Accordingly, girls' mathematical creativity was significantly higher than boys' ($p<0.05$).

A single-factor MANOVA analysis was conducted to determine whether students' mathematical creativity and achievement differed by grade level. Before this analysis, Box's M Test was performed for the equivalence of covariance matrices, and according to the results of this test, it was seen that the covariance matrices were not significantly equal ($M = 34.49$, $F(9, 1586664.47) = 3.80$, $p < 0.01$). According to this result, instead of Wilks' Lambda results from the single-factor MANOVA analysis, Pillai's Trace results, which are more resistant to situations where covariance matrices are not equal and are widely used, will be used. The results of this analysis indicated a significant difference in students' mathematical creativity and achievement according to grade level (Pillai's Trace = 0.870, $F(2, 6) = 1309.55$, $p < 0.01$). The descriptive statistics result of the single-factor ANOVA Test conducted in independent samples to determine the source of this difference is presented in Table 6, and the inferential statistics and Post Hoc Test results are presented in table 7.

Table 6

Descriptive results regarding students' mathematical creativity and achievement by grade level

Dependent Variable	Grade	N	$\bar{x}$	SD	SE
Mathematical Creativity	Grade 5	94	7.86	4.01	.41
	Grade 6	112	7.63	3.88	.37
	Grade 7	89	7.74	3.72	.39
	Grade 8	103	7.74	3.94	.39
	Total	398	7.74	3.88	.19
Success	Grade 5	94	64.79	20.30	2.09
	Grade 6	112	45.22	17.47	1.65
	Grade 7	89	47.98	24.50	2.60
	Grade 8	103	52.86	26.62	2.62
	Total	398	52.44	23.50	1.18

According to Table 6, both the mean mathematical creativity ($\bar{x} = 7.86$, $SD = 4.01$) and the mean achievement ($\bar{x} = 64.79$, $SD = 20.30$) of 5th-grade students are higher than those of other grade levels.

While the variances of students' mathematical creativity across grade levels are equal ($p>.05$), their variances across grade levels are not equal ($p<.05$). Therefore, the Welch Test results are presented along with a single-factor ANOVA to determine whether there is a significant difference in achievement across grade levels.

Table 7

ANOVA results regarding students' mathematical creativity and achievement by grade level

Dependent Variable	Source of Variance	SS	df	MS	F	p	η^2	Source of Difference
Mathematical Creativity	Between Groups	2.72	3	.91	.060	.981		
	Within Groups (Error)	5967.12	394	15.15				
	Total	5969.84	397					
Success	Between Groups	21954.71	3	7318.24	14.62	.000	.100	5-6,5-7,5-8,
	Within Groups (Error)	197231.22	394	500.59				
	Total	219185.93	397					
Welch Testi			210.15		18.78	.000		

According to table 7, no significant difference existed in mathematical creativity between students at different grade levels ($F(3, 394) = .060$, $p>.05$). At the same time, a statistically significant difference was observed in their achievement ($F(3, 210.15) = 18.78$, $p<.01$, $\eta^2=.100$). This result indicates that grade level has a moderate effect on students' achievement, explaining 10% of the total variance.

Finally, a post-hoc test, Dunnett's C The test was employed to identify the source of the difference in students' achievement. Accordingly, fifth-grade students' achievement was significantly higher than 6th, 7th, and 8th grades ($p<.01$). There was no significant difference in students' achievement compared to other grade levels ($p>.05$).

A single-factor MANOVA was conducted to determine whether students' mathematical creativity and achievement differed according to family education level. Before this analysis, Box's M Test was conducted for the equality of covariance matrices. According to the results of this test, it was seen that the covariance matrices were significantly equal ($M=10.55$, $F(6, 2230353.68)=1.75$, $p>.05$). As a result of the single-factor MANOVA analysis, a significant difference was found in the mathematical creativity and achievement of the students according to gender (Wilks' Lambda .738, $F(4, 788)=32.30$, $p<.05$). The descriptive statistics results for the single-factor ANOVA Test in independent samples, which was conducted to determine the source of this difference, are given in table 8. In contrast, the inferential statistics result and Post Hoc Test results are given in table 9.

Table 8

Descriptive results regarding students' mathematical creativity and achievement according to family education level

Dependent Variable	Group	N	$\bar{x}$	SD	SE
Mathematical Creativity	MS	108	4.97	3.33	.32
	HS	127	8.02	3.64	.32
	U	163	9.36	3.38	.26
	Total	398	7.74	3.88	.19
Success	MS	108	39.91	18.01	1.73
	HS	127	50.35	23.58	2.09

Dependent Variable	Group	N	$\bar{x}$	SD	SE
	U	163	62.36	22.34	1.75
	Total	398	52.44	23.50	1.18

Table 8 shows that both the mean mathematical creativity ($\bar{x}$ = 9.36, SD = 3.38) and the mean achievement ($\bar{x}$ = 62.36, SD = 22.34) of students from university-educated families are higher than the mean achievement ($\bar{x}$ = 62.36, SD = 22.34) of students from different educational backgrounds.

While the variances of students' mathematical creativity are equal ($p>0.05$) according to family education level, their variances are not equal ($p<0.05$). Therefore, to investigate whether achievement differs significantly based on family education level, the results of the Welch Test are presented in Table 9, along with a single-factor ANOVA in independent samples.

Table 9

Descriptive results regarding students' mathematical creativity and achievement according to family education level

Dependent Variable	Source of Variance	SS	df	MS	F	p	η²	Source of Difference
Mathematical Creativity	Between Groups	1266.85	2	633.42	53.20	.000	.212	MS-HS, MS-U, HS-U
	Within Groups (Error)	4702.99	395	11.90				
	Total	5969.84	397					
Success	Between Groups	33562.16	2	16781.08	35.71	.000	.153	MS-HS,MS-U, HS-U
	Within Groups (Error)	185623.77	395	469.93				
	Total	219185.93	397					
Welch testi			254.95		41.50	.000		

Table 9 shows that students' mathematical creativity and achievement differ significantly according to family education level ($F(2, 395) = 53.20$, $p<0.05$), and there is a statistically significant difference between their achievement levels ($F(2, 254.95) = 41.5$, $p<0.01$).

This result demonstrates that family education level has a significant impact on students' mathematical creativity and achievement, explaining 21.2% and 15.3% of the total variance, respectively.

Finally, a post-hoc test, the Scheffe Test, was used to find the basis of the difference in students' mathematical creativity, and a post-hoc test, the Dunnett C Test, was used to identify the source of the difference in students' achievement. Accordingly, both the mathematical creativity and achievement of students from families with university degrees were significantly higher than those from families with high school and middle school degrees ($p<0.05$). Furthermore, both the mathematical creativity and achievement of students from families with high school degrees were significantly higher than those from families with middle school degrees ($p<0.05$).

A single-factor MANOVA analysis was conducted to determine whether students' mathematical creativity and achievement differed according to family economic status. Before this analysis, Box's M Test was performed to assess the equivalence of covariance matrices. The test results indicated that the covariance matrices were significantly unequal ($M=18.223$, $F(9, 667975.63) = 2.00$, $p<0.05$). Based on this result, the single-factor MANOVA analysis will use

Pillai's Trace, which is more robust to unequal covariance matrices and is widely used, instead of Wilks' Lambda. This analysis found a significant difference in students' mathematical creativity and achievement according to family economic status (Pillai's Trace =0.875, F (2,6) =1370.15, p<0.01). The descriptive statistics result of the single-factor ANOVA Test in independent samples conducted to determine the source of this difference is given in Table 10. The inferential statistics result and Post Hoc Test results are given in Table 11.

Table 10

Descriptive results regarding students' mathematical creativity and achievement according to family economic level

Dependent Variable	Economic Level	N	$\bar{x}$	SD	SE
Mathematical Creativity	L	76	4.25	3.32	.38
	M	68	7.56	3.51	.43
	H	165	8.45	3.42	.27
	VH	89	9.55	3.53	.37
	Total	398	7.74	3.88	.19
Success	L	76	36.38	15.97	1.83
	M	68	51.32	23.59	2.87
	H	165	54.64	22.29	1.74
	VH	89	62.92	24.08	2.55
	Total	398	52.44	23.50	1.18

Table 10 shows that both the mean mathematical creativity ($\bar{x}$ = 9.55, SD = 3.53) and the mean achievement ($\bar{x}$ = 62.92, SD = 24.08) of students from very high-income families are higher than the mean of families with different economic levels.

While the variances of students' mathematical creativity by family economic level are equal (p>0.05), their variances by achievement are not equal (p<0.05). Thus, to examine if there is a significant difference in achievement by grade level, the results of the Welch Test are also presented along with a single-factor ANOVA in independent samples.

Table 11

ANOVA results regarding students' mathematical creativity and achievement according to family economic level

Dependent Variable	Source of Variance	SS	df	MS	F	p	η^2	Source of Difference
Mathematical Creativity	Between Groups	1303.74	3	434.58	36.70	.000	.218	L-M, L-H, L-VH, M-VH
	Within Groups (Error)	4666.10	394	11.84				
	Total	5969.84	397					
Success	Between Groups	30256.48	3	10085.49	21.03	.000	.138	L-M, L-H, L-VH, M-VH, H-VH
	Within Groups (Error)	188929.45	394	479.52				
	Total	219185.93	397					
Welch Testi			182.1		29.15	.000		

Table 11 shows that students' mathematical creativity and achievement differed significantly according to family economic status (F (3, 394) = 36.70, p<0.01), and there was a statistically significant difference between their achievements ($F(3, 182.1) = 29.15$, $p<0.01$).

This result demonstrates that family economic status has a significant effect on both students mathematical creativity and achievement, explaining 21.8% and 13.8% of the total variance, respectively.

Finally, post-hoc tests, Scheffe and Dunnett C tests, were used to identify the source of differences in students' mathematical creativity and achievement. Accordingly, students from "Very High" economic status families had significantly higher mathematical creativity than students from "Low" and "Medium" economic status families ($p<0.05$). Furthermore, the mathematical creativity of students from "High" economic status families is significantly higher than that of students from "Low" economic status families ($p<0.05$). Finally, the mathematical creativity of students from "Medium" economic status families is significantly higher than that of students from "Low" economic status families ($p<0.05$). However, the mathematical creativity of students from "Very High" and "High" economic status families is similar ($p>0.05$).

On the other hand, the achievement of students from "Very High" economic status families is significantly higher than that of students from "High," "Medium," and "Low" economic status families ($p<0.05$). Similarly, the achievement of students from "High" economic status families is significantly higher than that of students from "Low" economic status families ($p<0.05$). Finally, the achievement of students from "Medium" economic status families is significantly higher than that of students from "Low" economic status families ($p<0.05$). However, the success of students from families with "High" and "Medium" economic levels is similar ($p>.05$).

Discussion, Conclusions and Recommendations

This study primarily aimed to examine middle school students' mathematical creativity and achievement in terms of individual factors such as grade level and gender, and environmental factors such as family education and economic status. To this end, it was concluded that there was a positive, linear, and moderately significant relationship between students' mathematical creativity and achievement. This result suggests that students' mathematical creativity and achievement increase or decrease simultaneously. This result is consistent with the positive relationship between mathematical creativity and achievement found in many studies in the literature (Kozlowski et al., 2019; Liu et al., 2022; Schoevers et al., 2020; Singh, 2015). It is also consistent with the quasi-experimental study conducted by Abdul Hamid and Kamarudin (2021) that a mathematical creativity approach increases mathematical achievement. This may be because students with high mathematical creativity skills are better able to reason, solve problems, establish patterns, and find alternative solutions (Hartaji et al., 2023). Conversely, students who are successful in mathematics may have developed these skills because they express their creative ideas more easily and use their creativity skills more boldly (Gunawan et al., 2022). To examine the interaction between mathematical achievement and mathematical creativity, as well as the sub-dimensions included in the definition of this creativity, in greater depth, it is recommended that various experimental studies be conducted.

When examining students' levels of mathematical creativity and achievement by gender, two main results emerge. First, the mathematical creativity levels of female students are significantly higher than those of male students. However, the low magnitude of gender's effect on mathematical creativity indicates that, although gender has a significant effect on mathematical creativity, this effect is limited. This result in favor of female students is consistent with the findings reported in several studies (Akar & Özber, 2018; Akbaş & Tümkaya, 2024; Bolat, 2019; Rifqy & Masamah, 2024; Ulusoy et al., 2025). However, Pham's (2014) finding that mathematical creativity does not differ according to gender in his study with middle school students partially contradicts these results. In this context, it is considered that the limited differences observed between female and male students may stem from male students being more successful in the fluency dimension of creativity and female students being more successful in the flexibility and originality dimensions, as stated by Annisa and colleagues (2024). Therefore, it is recommended that future research examine the sub-dimensions of mathematical creativity in greater detail in the context of gender.

The second finding is that girls and boys have similar levels of mathematical achievement. This result is consistent with the findings of studies conducted by Bozkurt and Bircan (2015) with fifth-grade students and by Çavdar (2019) with fourth-grade students. Furthermore, it is consistent with the findings of PISA 2022 results based on Turkish data, which also indicate that there is no significant difference in mathematical achievement based on gender (MEB, 2024). This situation may stem from the relative equalization of opportunities and facilities offered to female and male students in educational institutions (Deppen, 2018). On the other hand, this contradicts the findings of Kara and Özkaya (2022), who found that female students have higher mathematics achievement, and Lu et al. (2023), who found that male students have higher mathematics achievement when reading achievement is controlled for. These differing results in the literature can be explained by the trend that, despite female students' relatively low mathematics achievement in previous years, this gap has narrowed in recent years (Lega et al., 2025) and female students have even achieved higher levels of achievement in some samples. Therefore, it can be said that gender is no longer a sole determinant of mathematics achievement and currently has only a limited effect.

Two main findings emerge regarding students' mathematical creativity and mathematical achievement according to grade level. First, it was found that students' mathematical creativity did not show significant differences according to grade level. This result parallels Sarouphim's (2001) study, which found that students' mathematical creativity did not differ based on grade level. Similarly, it partially coincides with the result of Akgül's (2014) study, which found no difference in students' mathematical creativity in all grade levels except fifth grade. However, it contradicts the findings of Sak and Maker (2006), Tabach and Friedlander (2013), and Haavold (2018), which indicate that mathematical creativity differs according to elementary and middle school grade levels. In these studies, mathematical creativity increases as grade levels increase. Considering that mathematical creativity is a developable skill, it can be said that it is expected that creativity levels will increase as grade levels increase. Therefore, it is noteworthy that in the current study and in similar studies conducted in Turkey, no significant increase in students' mathematical creativity levels was observed as grade levels increased. This situation suggests that activities supporting students' creativity in mathematics teaching are not planned systematically enough. Therefore, it is recommended that tasks and activities that encourage students' mathematical creativity be regularly included in the teaching process. In addition, it is recommended that comprehensive studies be conducted in Turkey at different grade levels to determine the reasons why middle school students' mathematical creativity levels do not increase according to grade level. Secondly, it reveals that fifth-grade students' mathematics achievement is significantly higher than that of other grade levels, but there is no significant difference between other grade levels. This result partially aligns with the findings of Tosun (2025) with middle school students and Yang and colleagues (2024) with different samples, which revealed that math achievement differs significantly according to grade level. Similarly, it partially parallels the findings of West and colleagues (2015), who found that grade levels did not have a significant effect on students' math achievement scores. Notably, this result is similar to Akgül's (2014) finding that fifth-grade students' mathematical creativity differs from other grade levels, which is consistent with the results obtained in this study in terms of math achievement. This situation may indicate that fifth grade is a critical stage of development for students in terms of both mathematical creativity and mathematical achievement. Fifth grade may be a period in which students demonstrate a high level of motivation as they adapt to new learning environments, curricula, and assessment methods, given that it is an educational threshold where the transition from elementary school to middle school takes place. During this period, students in exam-focused countries such as Turkey may be able to express their thoughts more freely, develop alternative solutions, and show a more intrinsic interest in learning, as they are not yet significantly affected by the exam and performance pressures encountered in higher grades. This situation can be linked to the observed increase in both students' mathematical achievement and mathematical creativity levels. Therefore, this difference observed in fifth grade can be attributed to the cognitive transition period and educational stimuli, as well as the autonomy and flexibility that are still preserved in students' thinking processes. Indeed, it is frequently emphasized in the literature on creativity development that creativity is more pronounced in childhood and diminishes with age due to the influence of educational structures and social norms (Beghetto & Karwowski, 2017; Runco, 2012). In light of these results, it may be useful to examine in depth the cognitive, pedagogical, and developmental factors underlying why fifth-grade students differ from other grade levels in terms of mathematical creativity and mathematical achievement.

Two key findings emerge regarding students' mathematical creativity and achievement based on their families' educational level. First, students' mathematical creativity is found to differ significantly according to their family's educational level. It was found that the mathematical creativity of children from families with university and above education levels is higher than that of children from families with high school and middle school education levels, and that the creativity of children from families with high school education levels is also significantly higher than that of children from families with middle school education levels. In addition, it was determined that the family's educational level has a high impact on students' mathematical creativity. Therefore, it can be said that as the family's educational level increases, children's mathematical creativity also increases. This result is consistent with the studies by Suherman and Vidákovich (2024b) and Singh (1989), which show that students' mathematical creativity varies depending on the family's educational level.

Secondly, it was found that students' mathematics achievement differed significantly according to the educational level of their families. Similar to the results for mathematical creativity, it was concluded that the mathematical achievement of children from families with university and higher education levels was higher than that of children from families with high school and middle school education levels, and that the mathematical achievement of children from families with high school education levels was also significantly higher than that of children from families with middle school education levels. Accordingly, it can be said that as the family's educational level increases, the children's math achievement also increases, and the family's educational level has a high level of influence on student achievement. This result regarding math achievement is parallel to the results regarding mathematical creativity. Furthermore, this result is consistent with studies showing that children from families with university and higher education levels demonstrate higher mathematics achievement (Akbari et al., 2014; Külünk Akyurt, 2019; Çanakçı & Özdemir, 2015; Njuguna, 2021; Şahin, 2018; Umatgerieva & Dzhabrailova, 2024). The basis for this differentiation in terms of both mathematical creativity and mathematical achievement may lie in the fact that the educational level of families shapes children's learning environments and cognitive stimulation levels. According to social learning theory (Bandura, 1977), children model their parents' problem-solving, thinking, and learning styles by observing them. Therefore, children of parents with higher educational levels may grow up in a richer learning environment in terms of both cognitive strategies and attitudes toward learning.

Two key findings emerge regarding students' mathematical creativity and achievement based on their families' economic status. First, it is observed that students' mathematical creativity varies significantly according to their families' economic status. As the family's economic status increases, students' mathematical creativity also increases, indicating that the family's economic status has a strong influence on students' mathematical creativity. This result is consistent with previous studies (Acar et al., 2022; Araya et al., 2019; Fuadah et al., 2024; Kupczyszyn et al., 2023; Sarsani, 2011) that reveal a significant effect of family economic conditions on mathematical creativity.

Secondly, it has been observed that students' mathematics achievement levels vary significantly according to their families' economic status. It can be said that as the economic level increases, students' math achievement also increases and that the family's economic level has a high level of influence on achievement. This result is consistent with the study by Fox and Larke (2014), which found that the family's economic level creates a significant difference in students' math learning achievement. Additionally, studies showing that socioeconomic status has a strong effect on math achievement (Cogswell, 2019; Coşkun & Karakaya Özyer, 2023; Kocakaya et al., 2018; Oyelami et al., 2024; Yang, 2023) support the current finding. However, there are also a few research findings that contradict this result. For example, Sodikin's (2023) study reported that the family's economic level did not make a significant difference in students' math achievement. Overall, this study reached similar conclusions regarding both mathematical creativity and math achievement based on the educational and economic levels of the family. The main reason for this may be that families with high educational levels also have high economic incomes, and these two variables create a mutually reinforcing effect.

This study reveals that as the educational and economic level of the family increases, both students' mathematical creativity and mathematical achievement increase. This situation can be explained by the potential of families with high educational and economic levels to provide their children with enriched learning environments, attach a higher value to education, serve as positive role models, and ensure more effective participation in their children's learning processes. Indeed, as emphasized by Çarkoğlu and colleagues (2023) and Budiongan and colleagues (2024), variables such as the family's mathematical background, attitudes toward education, socioeconomic status, and professional position may play a role in this interaction. In this context, it is recommended that in-depth research be conducted on which of these variables are more effective on mathematical creativity and achievement. In this context, encouraging students from disadvantaged socioeconomic backgrounds to participate in artistic, cultural, and scientific activities that support their creativity and achievement in schools can be an important supporting factor for both their cognitive and creative development.

In conclusion, the study found a positive, moderate, and significant relationship between middle school students' mathematical creativity and their mathematics achievement. When examined by gender, it was determined that female students' levels of mathematical creativity were significantly higher than those of male students, but the effect size of this difference was low. In terms of math achievement, no significant difference was found between genders. While students' levels of mathematical creativity did not differ according to grade level, fifth-grade students' math achievement was found to be significantly higher than that of other grade levels. Finally, it was concluded that as both the educational and economic levels of the family increased, students' mathematical creativity and achievement also increased significantly and to a high degree.

Limitations and Future Research

Because this study is based on a cross-sectional design, the relationships between variables cannot be interpreted causally. In the future, the use of longitudinal or experimental designs could more robustly test the direct and indirect effects of mathematical creativity on achievement. The sample is limited to three public middle schools. Therefore, it is considered that this limits the generalizability of the findings. Furthermore, teacher attitudes, school climate, and students' self-efficacy levels were not included in the study. It is recommended that new studies include these variables.

Declarations

Acknowledgements: Not applicable.

Authors' contributions: All authors have played an equal role in all stages of the article. All authors have read and approved the final version of the work.

Competing interests: The authors declare that they have no financial or personal conflicts of interest with other individuals or organizations related to this research.

Funding: No support was received from any institution, organization, or individual for this research..

Ethics approval and consent to participate: This study was conducted in accordance with the ethical compliance requirements, based on the decision of the Erzincan Binali Yıldırım University Human Research Ethics Committee of Educational Sciences (dated 29/02/2024, Protocol No: 05/12) and the research permit of the Ministry of National Education (MEB No: MEB.TT.2024.000591). Prior to participation, all individuals were informed about the purpose, procedures, confidentiality principles, and voluntary nature of the study, and written informed consent was obtained.

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