Journal of Pedagogical Research
Volume 6, Issue 4, 2022
https://doi.org/10.33902/JPR.202215433

Research Article

Investigation of high school students' creative problem-solving attributes

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The aim of this survey design study was three-fold. First, to investigate the creative problem-solving attributes of high school students. Second, to examine whether any inter-relationships exist between sub-dimensions of creative problem-solving attributes. Third, to determine whether high school students' creative problem-solving attributes vary by gender, school type, and grade level. To this end, data were collected from a total of 435 high school students through the Creative Problem Solving Attribute Inventory. Correlation results indicated statistically significant correlations between the total creative score and sub-dimension scores. A significant difference in creative problem-solving skills was not found between gender and school type. Grade level was found to affect divergent thinking, convergent thinking, motivation, and general knowledge and skills only at a small level. However, as the grade level increased, the divergent thinking scores increased linearly. The convergent thinking, motivation, environment, general knowledge and skills, and total creative scores dropped in the 10th grade, but increased in the 11th and 12th grades.

Keywords: Creativity; Creative problem solving; Attributes of creativity; High school students

Article History: Submitted 18 April 2022; Revised 2 August 2022; Published online 18 August 2022

1. Introduction

Mathematical creativity and problem-solving skills are closely related at the school level (Chamberlin & Moon, 2005; Guilford, 1959; Liljedahl & Sriraman, 2006; Lin & Cho, 2011). The ability to solve problems creatively means finding suitable new solutions, designing original solutions, and mastering the basic skills of creativity (Hennessey & Amabile, 2010; Kattou et al., 2013; Kaufman & Sternberg, 2007). The ability to think creatively is inherent in every individual (The Organisation for Economic Cooperation and Development [OECD], 2019; Treffinger et al., 2006).

Polya (2014) argues problem-solving from a creative point of view by expressing that there is an invention, albeit a small one, in the solution of every problem. Even in a simple mathematical word problem, it can be used as a tool for students to solve the problem in as many unique and mathematically correct ways as possible (Niu & Zhou, 2017). According to Liljedahl and Sriraman (2006), mathematical creativity at the school level is the ability to come up with original solutions

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How to cite: Keleş, T. (2022). Investigation of high school students' creative problem-solving attributes. *Journal of Pedagogical Research, 6*(4), 66-83. https://doi.org/10.33902/JPR.202215433

to problems or see old problems in a new light. Routine problems (Polya, 2014), non-routine problems (Pitta-Pantazi & Christou, 2009), real-life problems (National Council of Teachers of Mathematics [NCTM], 2000; Treffinger et al., 2006; Zazkis & Holton, 2009), and ill-structured open-ended problems (Kwon et al., 2006) provide opportunities for students to improve their mathematical creativity potential.

In addition to applying previously learned solutions, creative potential is the ability to edit existing algorithms and rules effectively (Ervynck, 2002). One of the best ways to develop creative problem solving is to encourage students to solve problems in different or multiple ways (Leikin, 2009). In other words, solving a problem in different or multiple ways effectively develops creative problem solving (Leikin & Pitta-Pantazi, 2013; Posamenter & Krulik, 2008). It is stated that a student benefits more from solving a problem in three different ways than solving three different problems in the same way (Posamenter & Krulik, 2008; Zazkis & Holton, 2009). Solving a problem in a variety of ways encourages students to expand their creative abilities (Leikin & Pitta-Pantazi, 2013; Zazkis & Holton, 2009). In comparison to their peers, students with creative problem-solving skills can come up with different and original solutions to problems (Chamberlin & Moon, 2005; Csikszentmihalyi, 1996).

Creativity and creative problem solving are competencies needed for today's youth to improve themselves (OECD, 2019). Moreover, problem-solving and creativity are among the most important skills to be developed in 21st-century skills (World Economic Forum [WEF], 2020). According to Kaufman and Beghetto (2009), creativity is one of the world's most important economic resources today. Therefore, supporting the creativity of all students is one of the main goals of today's school education (Niu et al., 2017; OECD, 2019). Mathematics is a field where individuals' creative performances emerge very clearly (Özyaprak, 2019). Mathematical creativity has become an accepted skill that every student should develop (Mann, 2005). Creative problem solving has been associated with personality traits by many researchers (Cho, 2003; Guilford, 1959; Kim et al., 2003; Urban, 2003).

Creativity in math problem solving requires various attributes such as divergent thinking (Kwon et al., 2006; Runco, 2003; Urban, 2003), convergent thinking (Cropley, 2006; Runco, 2003), motivation (Urban, 2003), environment (Hong & Aqui, 2004; Kauffman & Baer, 2004; Lin & Cho, 2011; Mann, 2006), and general knowledge and skills (Urban, 2003). These attributes interact with each other in the realization of creativity. In short, each attribute does not work independently of the other in creative problem solving (Cho, 2003; Urban, 2003). Mathematical creativity may be jeopardized by focusing on only one of the students' creative problem-solving attributes. In this sense, creativity can be realized once these attributes have been developed in a balanced manner.

1.1. Literature Review

Studies on creative problem-solving in mathematics examined students' mathematical creativity through divergent thinking (e.g. Biçer et al., 2020; Kahveci & Akgül, 2019; Kwon et al., 2006; Leikin & Pitta-Pantazi, 2013; Mann, 2009; Sriraman, 2009), convergent and divergent thinking (Urban, 2003; Guignard & Lubart, 2007), or five creative problem-solving attributes (Gaglione, 2021; Lin, 2010; Lin & Cho, 2011; Paf & Dinçer, 2021; Teseo, 2019). This paper focuses on creative problem-solving attributes.

In divergent thinking, multiple ideas are proposed in a fluency, flexible, innovative, and detailed way to solve a problem (Runco, 2008; Runco et al., 2006; Treffinger et al., 2006). Convergent thinking synthesizes information from multiple sources to create the single best possible answer to a problem (Cropley, 2006; Teseo, 2019). This type of thinking requires accumulating knowledge, recognizing the relationships between concepts, applying knowledge, and utilizing traditional decision strategies (Cropley, 2006). While divergent thinking emphasizes the diversity of answers and the quality of outcomes (Guignard & Lubart, 2007; Runco & Acar, 2019; Treffinger et al., 2006), convergent thinking is the ability to choose a single most appropriate answer from among various alternatives to solve a problem (Lin, 2010; Runco & Acar, 2019).

Although convergent thinking seems quite the opposite of divergent thinking in creative production, in fact, divergent and convergent thinking complement each other in one's success in creativity (Cropley, 2006; Runco & Acar, 2019). New ideas generated through divergent thinking may be irrelevant or inadequate without convergent thinking. Therefore, convergent thinking evaluates various solutions, recognizes the connection between the problem and solutions, and finds the best solutions using logical and critical thinking (Cropley, 2006). In addition, divergent and convergent thinking interact constantly when solving creative problems (Cropley, 2006; Lin, 2010; Teseo, 2019). Moreover, it is argued that creativity requires divergent and convergent thinking (Cropley, 2006; Runco, 2003). Historically, creativity has been seen as only divergent thinking (Guilford, 1959), but recent research has shown that it is multifaceted and complex and should be viewed holistically (e.g. Gaglione, 2021; Kim et al., 2003; Lin, 2010; Teseo, 2021).

The emotional factors that affect a person's willingness to initiate, maintain, and complete problem solving are closely related with motivation, including curiosity, risk-taking, focus, perseverance, effort, and persistence (Hennessey, 2019; Sheffield, 2009; Taşcılar, 2021). Those who are highly motivated are more resilient to challenges, which helps them solve problems creatively. There are two important sources of motivation: intrinsic motivation and extrinsic motivation (Hennessey, 2019; Taşcılar, 2021). The intrinsic motivation is based on an individual's internal focus and motivation, such as working solely for pleasure and enjoyment and doing something they are interested in or curious about. Learning is powerfully influenced by emotions. The human brain enjoys solving creative problems, and this pleasure strengthens it (Cercone, 2006).

In extrinsic motivation, rewards are accessed from external sources (Hennessey, 2019) such as recognition is getting high grades, test scores, and rewards from parents or teachers. Gagné (2010) emphasized that motivation is important for developing creativity. Studies have found a significant and positive relationship between creative thinking and intrinsic motivation (Cooper & Jayatilaka, 2006; Lin, 2010; Prabhu et al., 2008; Renzulli & Reis, 2014). On the other hand, some studies found a negative relationship between extrinsic motivation and creativity (Prabhu et al., 2008).

A person with a high level of motivation in divergent and convergent thinking will be limited in his ability to generate alternative solutions for a problem if he does not possess sufficient knowledge and skills (Teseo, 2019). Therefore, mathematical content knowledge contributes greatly to mathematical creativity (e.g. Ervynck, 2002; Hong & Milgram, 2010; Runco et al., 2006). To put it another way, without sufficient mathematical knowledge, a person cannot be creative (Csikszentmihalyi, 1996). According to Hong and Milgram (2010), creativity is a content-specific phenomenon and each field requires its own theoretical and practical approaches. Several studies supported this claim by establishing that mathematical achievement and creativity were significantly related (Baer et al., 2004; Kattou et al., 2013; Kaufman & Baer, 2004; Mann, 2009).

The environment that supports and rewards creativity encourages and improves one's creativity (Sak, 2016). The environment consists of family, peers, teachers, and schools. The environment in this study is limited to the parent. Parents provide an undeniable support and environment to nurture and develop their children's mathematical creativity (Lin, 2010; Teseo, 2019). However, parents are often not prepared for this task (Sheffield, 2009). Many researchers have revealed that the environment, especially the family factor, impacts creativity (e.g. Campbell & Uto, 1994; Gute et al., 2008; Tordjman et al., 2021). Discipline is generally not perceived as authoritarian by parents of creative children (Kanlı, 2019). Parents who tend to nurture and develop their children's creative and critical thinking skills are more likely to be open to these opportunities (Cook et al., 2011; Gute et al., 2008). Lin and Cho (2011) found that the family environment significantly affects students' creative problem-solving skills. In the study conducted by Teseo (2019), a significant and positive (r = .70) relationship was found between creative problem solving and the environment.

In their study with 409 middle school fifth and sixth-grade students, Lin and Cho (2011) revealed that divergent thinking, convergent thinking, environment, and motivation predict students' general knowledge and skills. Another study by Teseo (2019) found significant relationships between motivation and convergent thinking (r = .531), motivation and general knowledge and skill (r = .515), between divergent thinking and convergent thinking (r=.494), between environment and convergent thinking (r =. 439). Gaglione (2021) found that the learning environment explained 29% of the variance in students' perceptions of creative problem-solving skills in a study conducted with 114 middle school students at different grades. Studying 1098 fifth, sixth, seventh, and eighth-grade secondary school students, Paf and Dinçer (2021) found students had a high problem-solving skills. In addition, while it was determined that there was a significant difference in favor of girls in terms of gender, no significant difference was found in terms of grade levels. A meta-analysis conducted by Da Costa et al. (2015) showed that divergent thinking and intrinsic motivation were positively associated with creativity.

Several studies have examined gender differences in creative thinking (e.g. He & Wong, 2021; Hong & Aqui, 2004; Sokić et al., 2021; Walia, 2012). Some studies have shown that boys score higher (DeMoss et al., 1993; He & Wong, 2021), and in others they have shown that girls score higher than boys. Some other studies found no significant difference between gender and creativity or creative behavior (Baer & Kaufman, 2008; Hong & Migram, 2010; Walia, 2012). For instance, Walia (2012) uncovered no significant difference between male and female students regarding achievement levels and mathematical creativity. Also, a meta-analysis by Taylor and Barbot (2021) showed that gender differences in creativity were inconsistent across different domains and tasks. It is evident from these results that studies on gender differences in creativity are inconsistent (Abraham, 2016).

There are also inconsistent results when students' creativity is compared according to class/age differences (e.g. Biçer et al., 2020; Charles & Runco, 2000; Guignard & Lubart, 2007; Lin & Cho, 2011). In their study, Sak and Maker (2006) examined the relationship between age, education duration, and domain-specific knowledge in the development of mathematical creativity of 841 students, and revealed that the students in the upper classes scored higher in divergent thinking than the students in the lower classes. It has also shown that years of education contribute significantly to students' creativity. Another study by Charles and Runco (2000) found that fourth-grade students exhibited higher levels of flexibility, fluency, and originality, as well as divergent thinking than fifth-grade students. Runco (2003) suggested that children's creativity development may show an age-dependent curvilinear trajectory (inverted U). Hong and Migram (2010) examined general and specific creative thinking abilities in gender, age, class, ethnicity, and learning disability over three different groups (high school-college, elementary students, and preschool children). Although gender didn't significantly differ in general and specific creative thinking abilities in high school, grade level had a significant effect on specific creative thinking abilities in academic problem-solving. It was stated that the higher the grade level, the higher the special creative thinking scores. In another study, Biçer et al. (2020) examined the effect of grade level on the mathematical creativity of 3rd, 4th, and 5th-grade elementary students and found no significant difference.

1.2. Importance of the Study

The development of students' creativity is very important for economic, scientific, social, and artistic-cultural progress (Hennessey & Amabile, 2010; Mann, 2006). Creativity is not a static feature but a dynamic feature that can be developed with experience and teaching (Leikin, 2009; Liljedahl & Sriraman, 2006). It should be noted that creative problem-solving attributes can be developed and that the development of these attributes can bring the creative problem-solving skills of the individual to the highest point (Özyaprak, 2019). However, these attributes do not usually arise spontaneously. Teachers and other important adults in the student's life contribute greatly to developing these attributes (Sheffield, 2009). Studies on the mathematical creativity of Turkish students have emphasized the evaluation of students' divergent thinking abilities (Kahveci & Akgül, 2019). However, little is known about the creative problem-solving attributes of high school students through divergent thinking, convergent thinking, motivation, general knowledge and skills, and environmental components. In order to cultivate and develop high school students' creative problem-solving skills, it is necessary to understand and measure creative problem-solving from a comprehensive perspective, including all relevant aspects. This study will provide valuable information to stakeholders in education. Thus, important clues are obtained for improving weak attributes of students in creative problem solving and for enhancing their strong attributes. It is vital to determine the creative problem-solving attributes of students, especially during the high school years, when important choices like career and university can be made. However, although many studies reveal the creativity of primary and secondary school students (e.g. Gaglione, 2021; Guignard & Lubart, 2007; Kahveci & Akgül, 2019; Lin, 2010; Sak & Maker, 2006; Teseo, 2019), there are only a few that reveal the creativity of high school students (Hong & Migram, 2010; Hong & Aqui, 2004). The limited number of studies has been a major factor in working with high school students.

1.3. Aim of the Study and the Research Questions

The aims of this study were (a) to determine the creative problem-solving skills of high school students, (b) to investigate whether there was any relationship between sub-dimensions of creative problem-solving attributes (CPSA)(divergent thinking, convergent thinking, motivation, environment, general knowledge and skills) in high school students, and (c) to identify whether gender, school type, and grade difference exist in creative problem-solving attributes of high school students. Accordingly, the study aims to address the following five research questions:

RQ 1) What are the creative problem-solving skill levels of high school students?

RQ 2) Is there any relationship between the sub-dimensions of creative problem-solving of high school students?

RQ 3) Is there any gender difference in the creative problem-solving attributes of high school students?

RQ 4) Is there any school type difference in the creative problem-solving attributes of high school students?

RQ 5) Is there any grade level difference in the creative problem-solving attributes of high school students?

2. Method

2.1. Research Design

The research was carried out in a survey design with a quantitative approach. Several general survey models were used in the research were single, relational survey, and causal comparison models. Single survey models describe variables of the problem separately (Karasar, 2016). Since the first question of the research was handled in line with the single survey model, frequency, percentage, and average score calculations were made regarding the degree of agreement of high school students with statements emphasizing their creative problem-solving attributes. The relational survey model aims to determine the existence and/or degree of change between two or more variables (Fraenkel & Wallen, 2006; Karasar, 2016). Second, the relational survey model was used to examine whether there was a relationship between the sub-dimensions of creative problem-solving attributes in high school students. Causal comparison, on the other hand, is a type of research aimed at determining the variables that affect the causes of an emerging or existing situation or the consequences of an effect (Büyüköztürk et al., 2016). The causal comparison model was used to examine whether the creative problem-solving attributes of high school students in the study's third, fourth and fifth research questions differ according to gender, school type, and grade level.

2.2. Participants

Two science high schools and four Anatolian high schools participated in the study within the scope of the project school, located in two different districts of Bursa in 2021-2022 academic year. The study used criterion sampling as a purposive sampling method. Using a purposeful sampling method allows for in-depth research by selecting situations with abundant information based on the objective of the study (Büyüköztürk et al., 2016). The basis of criterion sampling is that the person, object, or situation to be selected meets a specific criterion (Cohen et al., 2007). In this study, participants were selected according to the criteria of science high school and Anatolian high school.

To enroll in these high schools, it is necessary to be successful in the central exam within the High School Transition System (LGS) scope. While Science High School students included in the study are in the top 0.01% to 0.65% of the LGS exam in Turkey, Anatolian High School students are in the top 0.66% to 6.16% (Ministry of National Education [MoNE], 2021). Permissions were obtained from Bursa Provincial Directorate for National Education to collect the data in the research. A total of 435 students participated into the study. Of the students, 247 (56.8%) were female, and 188 (43.2%) were male. The demographic information of the students is given in Table 1.

Table 1
Descriptive statistics on the number of students participating in the research

School Type	Gender	9th grade	10th grade	11th grade	12th grade	Total
Science High School	Female	25	30	42	29	126
	Male	38	25	21	16	100
Anatolian High School	Female	35	50	27	9	121
	Male	38	31	18	1	88
	Total	136	136	108	55	435

2.3. Data Collection Tool

The Creative Problem-Solving Attributes Inventory was used to measure students' creative problem-solving skills. The scale was developed by Lin (2010) based on the *Dynamic System Model of Creative Problem Solving Skills* developed by Cho (2003). The scale was adapted to Turkish by Baran-Bulut et al. (2018). The adaptation study continued with 856 secondary school students. As a result of the adaptation, a five-factor structure consisting of 40 items was revealed. The scale consists of 10 items of divergent thinking (e.g., "I can understand problem from different directions."), 8 items of convergent thinking (e.g., "I find out the main task of the problem."), 6 items of motivation (e.g., "I have strong interests in finding out problems."), 11 items of environment (e.g., "My parents wait until I come up with many ideas when I am facing with a problem."), 5 items of general knowledge and skill (e.g., "The questions in homework or tests are easy for me."). The internal consistency reliability coefficient of the original scale (Cronbach Alpha) was .79 for divergent thinking, .78 for convergent thinking, .73 for motivation, .88 for environment, and .77 for general knowledge and skill.

The internal consistency reliability coefficients of the current study were .83, .76, .80, .92, .79, and .92, respectively, for divergent thinking, convergent thinking, motivation, environment, general knowledge and skills, and overall scale. In this case, the obtained values proved that the scale was reliable in measuring the attributes (Büyüköztürk, 2012). A five-point likert scale was adopted, where 1 represented 'never, and 5 'always'. The minimum and maximum scores of the divergent thinking, convergent thinking, motivation, environmental dimension, and general knowledge and skills dimension are 10 and 50, 8 and 40, 6 and 30, 11 and 55, and 5 and 25, respectively. The minimum and maximum total scores that can be obtained from the scale are 40 and 200. The mean score values for the scale were calculated as the arithmetic mean reference interval $(5-1) \div 5 = 0.80$. The averages obtained were interpreted based on the range values:

very low ($1.00 \leq \overline{X} \leq 1.80$), low ($1.81 \leq \overline{X} \leq 2.60$), medium ($2.61 \leq \overline{X} \leq 3.40$), high ($3.41 \leq \overline{X} \leq 4.20$), and very high ($4.21 \leq \overline{X} \leq 5.00$). Mean scores were calculated by summing the values of the items and dividing by the number of items. The Confirmatory Factor Analysis fit index of the Creative Problem-Solving Attributes Inventory were as follows: χ^2/df = 2.83, RMSEA= .065, CFI= .82, and SRMR= .068. A value of χ^2/df less than 3 corresponds to a perfect fit, and a value of less than 5 corresponds to an acceptable fit (Çokluk et al., 2016; Karagöz, 2021). Based on the χ^2/df value calculated in this study implies that the model fit is perfect. Values of RMSEA and SRMR less than .05 indicate excellent fit, less than .08 indicate good fit, and less than .10 indicate poor fit (Çokluk et al., 2016; Karagöz, 2021). The RMSEA and SRMR values calculated in this study indicate a good fit. CFI value above .90 indicates a good fit, while a lower value indicates a poor fit (Çokluk et al., 2016). The calculated CFI value indicates a poor fit. The validity and reliability analyzes of the CPSA indicate that the scale is valid and reliable, and the five-factor structure of the scale is compatible with the collected data set.

2.4. Data Analysis

Quantitative data analysis was carried out using the SPSS 23.0 statistical package program. First of all, the extreme values in the data set were examined, and two students were removed from the data set. In the study, Kurtosis and Skewness values were examined in order to analyze whether the data showed a normal distribution. In this regard, descriptive statistical values for the data set are given in Table 2.

Table 2
Findings regarding the descriptive statistics of the data set

	Skewness	Kurtosis
Divergent Thinking	.046	.099
Convergent Thinking	−.370	.177
Motivation	−.187	−.218
Environment	−.740	.211
General Knowledge and Skills	−.134	.401
Total of CPSA	−.114	−.039

As the Kurtosis and Skewness coefficients of the data in the study ranged from -1 to +1, it was accepted that the data were normally distributed (Büyüköztürk, 2012; Tabachnick & Fidell, 2013). Following the normality tests, descriptive statistics, independent t-tests, and one-way ANOVA tests were conducted. Pearson Product Moments correlation coefficient (r) was calculated to examine the relationship between creative problem-solving attributes and their sub-dimensions. In addition, an independent t-test was applied to examine the differentiation of creative problem-solving attributes according to gender and school type. One-Way ANOVA was used to determine whether creative problem-solving attributes differ according to grade level.

In addition to statistical significance for independent t-tests and one-way ANOVAs, the effect size was determined to assess the degree of difference. The analysis tests were performed to reveal whether there is a significant difference between the compared averages but do not provide information about the size of the difference (Can, 2013). For this reason, in addition to statistical significance, effect size calculation was made in the study. With the effect size statistic eta-square (η^2), it was determined how much of the independent variable or factor explained the total variance in the dependent variable (Büyüköztürk, 2012). The effect value ranges between 0.00-1.00, and the .01 level is interpreted as a "small", the level .06 "medium" and the level .14 "large" effect size (Can, 2013). At the correlation level, the intervals determined by Büyüköztürk (2012) were taken as the basis and interpreted accordingly. Accordingly, an effect size of 0.30 was considered as low, 0.7 as medium and values greater than 1 were considered as high. Before the analysis, the equality of variances was examined through Levene's test. Because the equality of variances was met, Tukey test results were used in multiple comparisons. The significance level was established at .05.

3. Results

In this section, findings are presented in relation to the research questions.

3.1. Creative Problem-Solving Skill Levels of High School Students

Descriptive statistics for determining the creative problem-solving skill levels of high school students are given in Table 3.

Table 3
Descriptive statistics of creative problem-solving skills and sub-dimensions

	N	*m*	$\bar{X}$	$\bar{X}/m$	*SD*
Divergent Thinking	435	10	36.23	3.62	5.54
Convergent Thinking	435	8	30.02	3.75	4.59
Motivation	435	6	21.39	3.56	4.46
Environment	435	11	39.96	3.63	9.80
General Knowledge and Skills	435	5	17.73	3.54	3.19
Total of CPSA	435	40	145.34	3.63	19.47

Note. m: Number of Items

Analyzing students' creative problem-solving skill levels from high to low, convergent thinking is followed by total CPSA score, environment, divergent thinking, motivation, and general knowledge and skills. Moreover, the highest average score is in the dimension of convergent thinking while the lowest average score is in the dimension of general knowledge and skills. Overall, high school students have high levels of creative problem solving in general and in five sub-dimensions.

3.2. Correlation Coefficients between Creative Problem Solving Sub-dimensions

Correlation coefficients were calculated between the total of CPSA and five variables. Correlation coefficients were calculated to reveal whether there was a relationship between five sub-dimensions and total CPSA scores. Calculated correlations are given in Table 4.

Table 4
Correlation coefficients between the five subdimensions and the total of CPSA

	DT	*CT*	*M*	*E*	*GKS*	*Total of CPSA*
Divergent Thinking	1					
Convergent Thinking	.566**	1				
Motivation	.600**	.534**	1			
Environment	.208**	.281**	.220**	1		
General Knowledge and Skills	.493**	.376**	.474**	.186**	1	
Total of CPSA	.741**	.722**	.714**	.710**	.595**	1

Note. DT= Divergent Thinking; CT= Convergent Thinking; M= Motivation; E= Environment; GKS= General Knowledge and Skills; $^{*}p < .05$; $^{**}p < .01$

According to the findings in Table 4, the CPSA total score of high school students and five sub-dimensions are statistically significant to each other. Statistically positive significant correlations were found between the total of CPSA and divergent thinking, convergent thinking, motivation, and environment ($r = .741, p < .01$; $r = .722, p < .01$; $r = .714, p < .01$; $r = .710, p < .01$) which indicates a high correlation. On the other hand, a statistically positive significant correlation between total of CPSA, and general knowledge and skills ($r = .595, p < .01$), which is a moderare level. In addition, a statistically positive significant correlation between divergent thinking and convergent thinking, motivation, general knowledge and skills ($r = .566, p < .01$; $r = .600$, $p < .01$; $r = .493, p < .01$) at a medium level of correlation were calculayed. Additionally, a statistically positive significant correlation were found between convergent thinking and motivation, and general knowledge and skills ($r = .534, p < .01$; $r = .376, p < .01$), which was a medium correlation. A statistically positive significant correlation was also calculated between motivation and general knowledge and skills ($r = .474, p < .01$), which was a medium correlation. Finally, a low but statistically positive significant correlation between the environment and divergent thinking, convergent thinking, motivation, general knowledge and skills ($r = .208$, $p < .01$; $r = .281, p < .01$; $r = .220, p < .01$; $r = .186, p < .01$) were calculated.

3.3. Evaluation of CPSA in terms of Gender Variable

The findings regarding the evaluation of students' CPSA in terms of gender are presented in Table 5.

Table 5
CPSA of students with respect to gender

	Gender	*N*	$\bar{X}$	*SD*	*df*	*t*	*p*	η^2
Divergent Thinking	Female	247	36.00	5.328	433	−.984	.326	
	Male	188	36.53	5.816				
Convergent Thinking	Female	247	29.98	4.533	433	−.228	.820	
	Male	188	30.08	4.681				
Motivation	Female	247	21.06	4.224	433	−1.754	.080	
	Male	188	21.82	4.731				
Environment	Female	247	40.88	9.622	433	2.268	.024*	.012
	Male	188	38.74	9.933				
General Knowledge and Skills	Female	247	17.36	3.041	433	−2.782	.006*	.018
	Male	188	18.21	3.331				
Total of CPSA	Female	247	145.30	19.443	433	−.051	.959	
	Male	188	145.40	19.563				

Note. η^2 = Effect size; *$p < .05$

According to the independent t-test results in Table 5, there is a significant difference between the mean scores obtained from the sub-dimensions of environment and general knowledge and skills and the gender variable ($t = 2.268$; $p < .05$; $t = -2.782$; $p < .05$), and this difference was found to be in favor of girls in terms of environment and in favor of boys in terms of general knowledge and skills. No statistically significant difference was found between divergent thinking ($t = -.984$; $p > .05$), convergent thinking ($t = -.228$; $p > .05$), motivation ($t = -1.754$; $p > .05$), and total CPSA ($t = -.051$; $p > .05$) means scores of the scale, and the gender variable. However, it is seen that the average scores of divergent thinking, convergent thinking, motivation, and CPSA total score are higher for male students than for female students. The size of the significant difference between the means in the study was calculated with the effect size. The difference between the mean scores of females and males in the sub-dimension of the environment ($\eta^2 = .012$) is small. Similarly, the difference between the mean scores of females and males in the sub-dimension of general knowledge and skills ($\eta^2 = .018$) was found to be small.

3.4. Evaluation of CPSA in Terms of the Variable of School Type

Table 6 summarizes the findings regarding the evaluation of students' CPSA in terms of the school type.

Table 6
CPSA of students according to the variable of school type

	School type	N	$\bar{X}$	SD	df	t	p
Divergent Thinking	Science High School	226	36.24	5.396	433	.044	.965
	Anatolian High School	209	36.22	5.713			
Convergent Thinking	Science High School	226	30.18	4.637	433	.747	.456
	Anatolian High School	209	29.85	4.549			
Motivation	Science High School	226	21.47	4.659	433	.379	.705
	Anatolian High School	209	21.31	4.246			
Environment	Science High School	226	39.53	9.391	433	−.931	.352
	Anatolian High School	209	40.41	10.235			
General Knowledge and Skills	Science High School	226	17.71	3.330	433	−.142	.887
	Anatolian High School	209	17.75	3.048			
Total of CPSA	Science High School	226	145.15	19.827	433	−.216	.829
	Anatolian High School	209	145.55	19.127			

Note. $^{*}p < .05$

According to the independent t-test results in Table 6, there is no significant difference between the students' divergent thinking ($t = .044$; $p > .05$), convergent thinking ($t = .747$; $p > .05$), motivation ($t = .379$; $p > .05$), environment ($t = -.931$; $p > .05$), general knowledge and skills ($t = -.142$; $p > .05$), total of CPSA ($t = -.216$; $p > .05$) score averages, and the school type variable. However, while the mean scores of divergent thinking ($\bar{X} = 36.24$), convergent thinking ($\bar{X} = 30.18$), and motivation ($\bar{X} = 21.47$) sub-dimensions are higher for Science High School students, it is seen that the environment ($\bar{X} = 40.41$), general knowledge and skills ($\bar{X} = 17.75$), and total of CPSA ($\bar{X} = 14.55$) are higher for Anatolian High School students.

3.5. Evaluation of CPSA in Terms of the Variable of Grade

Descriptive statistics regarding the evaluation of students' CPSA in grade-level variables are presented in Table 7, and one-way ANOVA test results are presented in Table 8.

Table 7
Descriptive statistics for CPSA according to the variable of grade

	$\bar{X}$	SD	Grade	N		$\bar{X}$	SD
Divergent Thinking	35.52	5.795	9^{th} grade	136	Environment	40.43	9.360
	35.61	5.576	10^{th} grade	136		39.41	9.857
	37.03	5.151	11^{th} grade	108		40.00	10.567
	37.92	5.131	12^{th} grade	55		40.03	9.384
Convergent Thinking	30.04	4.504	9^{th} grade	136	General Knowledge and Skills	18.30	2.997
	29.23	4.817	10^{th} grade	136		17.16	3.239
	30.21	4.444	11^{th} grade	108		17.72	3.120
	31.58	4.188	12^{th} grade	55		17.73	3.519
Motivation	21.27	4.476	9^{th} grade	136	Total of CPSA	145.58	19.919
	20.68	4.168	10^{th} grade	136		142.12	19.425
	21.61	4.763	11^{th} grade	108		146.59	18.660
	23.01	4.169	12^{th} grade	55		150.29	19.182

The data in Table 7 show a linear increase in divergent thinking mean scores as grade level increases. Additionally, the convergent thinking, motivation, environment, general knowledge and skills, and total CPSA scores do not increase linearly with grade level. While mean scores for convergent thinking, motivation, environment, general knowledge and skills, and total CPSA increased linearly in the 11th and 12th grades, a slump occurred in the 10th grade.

Tablo 8
CPSA of students according to the variable of grade

	Source of Variation	*Sum of Squares*	*df*	*Mean Square*	*F*	*p*	*η2*	*Significant differences*
Divergent Thinking	Between Groups	347.937	3	115.979	3.847	.010*	.026	9-12
	Within Groups	12993.612	431	30.148				10-12
	Total	13341.549	434					
Convergent Thinking	Between Groups	221.979	3	73.993	3.570	.014*	.024	10-12
	Within Groups	8933.690	431	20.728				
	Total	9155.669	434					
Motivation	Between Groups	220.556	3	73.519	3.764	.011*	.025	10-12
	Within Groups	8417.435	431	19.530				
	Total	8637.991	434					
Environment	Between Groups	70.903	3	23.634	.245	.865		
	Within Groups	41649.433	431	96.634				
	Total	41720.336	434					
General Knowledge and Skills	Between Groups	88.351	3	29.450	2.924	.034*	.019	9-10
	Within Groups	4340.715	431	10.071				
	Total	4429.067	434					
Total of CPSA	Between Groups	2931.652	3	977.217	2.606	.051	.017	10-12
	Within Groups	161637.236	431	375.028				
	Total	164568.887	434					

Note. *p<.05

According to the one-way ANOVA results in Table 8, significant differences was found between the scores of high school students in the dimensions of divergent thinking ($F_{(3-431)} = 3.847$; $p < .05$), convergent thinking ($F_{(3-431)} = 3.570; p < .05$), motivation ($F_{(3-431)} = 3.764; p < .05$), and general knowledge and skills ($F_{(3-431)} = 2.924; p < .05$) and the grade level variable. In addition, there is no significant difference between students' CPSA total scores ($F_{(3-431)} = 2.606; p > .05$) and environmental scores ($F_{(3-431)} = .245; p > .05$) in terms of grade variables. In the study, the effect size statistics of the class level variable were also calculated eta-square. When the eta-square value related to divergent thinking ($\eta^2 = .026$), convergent thinking ($\eta^2 = .024$), motivation ($\eta^2 = .025$), general knowledge and skills ($\eta^2 = .019$), and total of CPSA ($\eta^2 = .017$) were considered, the effect sizes in terms of grade variable were found at small level.

According to the results of the Tukey test, which was conducted to determine between which groups the difference emerged in the ANOVA test, the analysis of the divergent thinking sub-dimension of the scale revealed that the average score of the 12th grade students ($\bar{X} = 37.92$) was higher than the average score of the 9th ($\bar{X} = 35.52$), and 10th grade students ($\bar{X} = 35.61$). As a result of the analysis of the convergent thinking sub-dimension of the scale, it was revealed that the average score of the 12th grade students ($\bar{X} = 31.58$) was higher than the average score of the 10th grade students ($\bar{X} = 29.23$). Similarly, in the motivation sub-dimension of the scale, the average score of the 12th grade students ($\bar{X} = 23.01$) was found to be higher than the average score of the 10th grade students ($\bar{X} = 20.68$). As a result of the analysis of the general knowledge and skills sub-dimension of the scale, it was revealed that the average score of the 9th grade students ($\bar{X} = 18.30$) was higher than the average score of the 10th grade students ($\bar{X} = 17.16$).

4. Discussion and Conclusion

4.1. Creative Problem Solving Attributes of High School Students

One of the main results of this investigation is that high school students have high levels of creative problem solving in general and five sub-dimensions. The students' divergent thinking, convergent thinking, motivation, environment, general knowledge and skill dimensions, and total

CPSA mean scores were quite high. The results of student selection for the high schools where the research was conducted, and the fact that these two high school types are preferred by high-achieving students indicate that this result is an expected result. The fact that the students are from qualified high schools such as Science High School and Anatolian High School indicates that creative problem solving is correlated with IQ (Sak, 2016). Literature emphasizes the importance of the environment, especially families and teachers, for developing creativity in students (Cook et al., 2011; Gute et al., 2008; Sak & Maker, 2006; Tordjman et al., 2021). The high level of creativity scores of these students suggests that their teachers and families may support creative problem-solving. Similarly, in many studies in the existing literature, it has been found that the mean scores of divergent thinking (e.g. Guignard & Lubart, 2007; Kahveci & Akgül, 2019; Lin & Cho, 2011; Mann, 2009; Russo, 2004; Teseo, 2019), motivation (Lin, 2010; Renzulli, 2005), environment (Gute et al., 2008) sub-dimensions, and total CPSA (Gaglione, 2021; Paf & Dinçer, 2021; Teseo, 2019) are high. Paf and Dinçer (2021) stated that middle school (5th, 6th, 7th and 8th grade) students have high average scores on creative problem-solving skill levels and sub-dimensions. In addition, it was determined that the lowest average score was in the general knowledge and skill dimension. Considering the studies in the literature, it can be claimed that the current study also reveals similar results.

4.2. Relationship between Creative Problem Solving Attributes of High School Students

In the study, it was observed that there were significant positive relationships between the total of CPSA and all five sub-dimensions. Among the sub-dimensions, divergent thinking has the highest correlation with both motivation and convergent thinking. This supports that divergent and convergent thinking are not mutually exclusive processes but always interact (Cropley, 2006; Lin, 2010; Runco & Acar, 2019; Teseo, 2019). Previous studies have emphasized a relationship between divergent thinking and convergent thinking. For example, various studies determined a positive and significant relationship between the average scores of divergent thinking and convergent thinking (Lin, 2010; Lin & Cho, 2011; Runco & Acar, 2019; Teseo, 2019). Students with high scores in divergent and convergent thinking demonstrate strong problem-solving skills. Creativity is closely related to motivation (Cooper & Jayatilaka, 2006; Da Costa et al., 2015; Hennessey, 2019; Renzulli & Reis, 2014; Prabhu et al., 2008; Tordjman et al., 2021) and that motivation is effective in the transformation of intelligence into talent (Gagné, 2010; Taşcılar, 2021) has been revealed by many researchers. The findings also support the idea that high IQ combined with very high motivation leads to high creativity (Sak, 2016). All sub-dimensions are moderately related except for the environment dimension. The environment dimension is associated with all sub-dimensions at a low level. Although these result is consistent with the Teseo (2019) study, it contradicts some other studies (e.g. Lin, 2010; Lin & Cho, 2011), showing that the environment is moderately related to other sub-dimensions. The environmental dimension consists of items that include the influence of the parent. It is thought that student maintain the same level under the influence of their parents.

A high level, positive and significant correlation was found between the total of CPSA and divergent thinking, convergent thinking, motivation, and environment. Some other studies supported these results (Cropley, 2006; Lin, 2010; Lin & Cho, 2011; Teseo, 2019; Urban, 2003). On the other hand, a medium, positive, and significant correlation was found between total creative problem solving and general knowledge and skills. It is clear from this study and other studies (e.g. Lin, 2010; Lin & Cho, 2011; Teseo, 2019) that creativity is closely related to divergent thinking, convergent thinking, motivation, environment, and general knowledge.

4.3. Gender Difference between Creative Problem Solving Attributes of High School Students

In examining the CPSA scores of the students based on gender, no significant differences were found in divergent thinking, convergent thinking, motivation, and total of CSPA. The mean scores for divergent thinking, convergent thinking, motivation, and total of CPSA of male students were higher than those of female students. While this result coincides with the results of the research

(He & Wong, 2021; Kaufman & Sternberg, 2007; Lin, 2010; Walia, 2012), it also contradicts the results of the research stating that gender differs in favor of girls on the creative problem (Hennessey, 2019; Hong & Aqui, 2004; Paf & Dinçer, 2021; Sokić et al., 2021). Similar to the result of the study, the rates of male and female students in PISA 2018 mathematics proficiency levels were very close to each other. Mathematics mean score for males were 456.51, while female students achieved 450.7. Specifically, the difference between boys and girls in PISA mathematics in Turkey did not change significantly between 2009 and 2018 (MoNE, 2019). In terms of creative problem-solving attributes, gender does not appear to be a variable. Other results showed a significant difference in favor of men in the sub-dimension of general knowledge and skills. In the sub-dimension of environment, a significant difference was observed in favor of girls. In this case, it can be claimed that girls are more influenced by their parents than boys in this case. These findings support the conclusion that the results of studies on gender differences in creative thinking are inconsistent (Abraham, 2016; Baer & Kaufman, 2008; Taylor & Barbot, 2021). It was also revealed that gender had a small effect on environment and general knowledge and skill sub-dimensions.

4.4. School Type Difference between High School Students' Creative Problem Solving Attributes

The CPSA of students was not significantly affected by school type when the school type variable was considered. However, it was determined that the mean scores of divergent thinking, convergent thinking, and motivation sub-dimensions were higher in Science High School students, while the mean scores of environment, general knowledge and skills, and total of CPSA were higher in Anatolian high school students. There may be a reason for this situation because the students are in the upper 6%, even though their percentiles in the central exam are different. According to the school type, students' creative problem-solving abilities are close. PISA 2018 mathematics performance shows that science high schools and Anatolian high schools have the highest scores, supports this result (MoNE, 2019). Similarly, in many studies, the importance of academic achievement and possessed content knowledge in creativity has been emphasized (Hong & Milgram, 2010; Lin & Cho, 2011). According to the research findings, school type is not a variable in terms of Science high school and Anatolian high school in terms of CPSA. Similarly, Berberoğlu and Kalender (2005) emphasized that especially science high school and Anatolian high school students are above the mathematics (numerical) average in line with the results they obtained in their study in which they conducted SSE and PISA analysis according to school types.

4.5. Grade Difference between High School Students' Creative Problem Solving Attributes

Another finding of the study was that there was a significant difference between grade levels and scores on divergent thinking, convergent thinking, motivation, and general knowledge and skills. However, it was revealed that grade level had a small effect on creative problem-solving skills. It was found that the average scores of 12th grade students in divergent thinking were higher than the mean scores of 9th grade and 10th grade students. As the grade level increases, divergent thinking scores increase linearly. Other studies have shown that mathematical creativity increases with grade level (Charles & Runco, 2000; Sak & Maker, 2006). Sak and Maker (2006) revealed that students in upper grades scored higher in divergent thinking than students in lower grades. In addition, this finding contradicts the research results that the creative development of children can show inverted-U depending on age (Runco, 2003).

It was revealed that the mean scores of 12th grade students in convergent thinking and motivation sub-dimension were higher than the mean scores of 10th grade students. In the general knowledge and skills sub-dimension, the mean scores of the 9th grade students were higher than the mean scores of the 10th grade students. In terms of creative problem-solving attributes, the 10th grade level constitutes the breaking point. The reason for the significant difference at the grade level may be that the 10th grade students are not in the process of preparing for the university exam, and they are more comfortable than other grade levels, since it is two more years. A slump in 10th grade and a linear increase in 11th and 12th grades emerged in convergent thinking, motivation, environment, general knowledge and skills, and total of CPSA. It can be said that Science High School and Anatolian High school students show a U-shaped development in terms of convergent thinking, motivation, environment, general knowledge and skills and total of CPSA mean scores according to grade level.

There was no significant difference between the grade level of the students and their total of CPSA scores and environmental scores. In this study, the environment focused on parents based on the questions in the CPSA. This situation revealed that the environment, like the family environment, supports creativity at every grade level (Gute et al., 2008; Kanlı, 2019; Lin, 2010; Sak, 2016; Teseo, 2019). It is supported that as the grade level increases, the family, that is, the environment, begins to play a more important role (Sak & Maker, 2010). In addition, Teseo (2019) emphasized that the environment is one of the most important factors in determining the creativity potential as well as the academic performance of the student. In addition, this result is in line with the research results where there is no significant difference in mathematical creativity scores according to grade level (Biçer et al., 2020; Paf & Dinçer, 2021).

A general evaluation of the research results revealed that high school students had high levels of creative problem-solving in general and in five sub-dimensions. Based on this result, divergent thinking, convergent thinking, motivation, environment, and general knowledge and skills should be supported in a balanced way at every grade level in order to develop students' creative problem-solving skills. Mathematical content knowledge plays a crucial role in mathematical creativity (Hong & Aqui, 2004; Mann, 2005) because it is difficult to provide divergent thinking without enough mathematical knowledge (Lin 2010). In order to develop divergent thinking, student should be confronted with open-ended questions, non-routine problems, and problems that are solved in multiple ways (Leikin, 2009; Leikin & Pitta-Pantazi, 2013; Posamenter & Krulik, 2008; Zazkis & Holton, 2009). By solving such problems, students will use different thinking skills. However, divergent thinking education alone does not produce creative students (Lin, 2010). On the other hand, if parents/schools emphasize convergent thinking skills instead of divergent thinking skills, students will be less creative and less risk-averse. In nurturing creativity, the environment and parents are essential (Lin, 2010; Teseo, 2019). However, it should not be forgotten that the pressures of the family negatively affect children's success (Campbell & Uto, 1994). For students to exhibit creative problem-solving performance, it is necessary to raise them to above-average levels in all attributes.

5. Suggestions and Limitations

Considering the research results, some suggestions are recommended. First, Since the method adopted in this study was to gain a greater understanding of the current situation, qualitative approaches may be more advantageous in examining the students' creative problem-solving attributes. Furthermore, the effect of environment designs that will develop these attributes can be examined through experimental studies.

This study has some limitations. The first limitation is that only the quantitative research design was used for data collection. Both quantitative and qualitative studies can also be conducted. The second limitation of this study is that the scale scores used in the study rely on student perceptions. Students' skills can later be measured using different data collection tools. Third, this study is limited to two types of schools that only accept high-scoring students. Further research can address different types of schools and even compare different countries.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by author.

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