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**To cite this article:**

Caliskan, C. & Altun, M. (2025). The impact of cognitive flexibility and classroom engagement on high school students' creative problem-solving skills. *International Journal of Education in Mathematics, Science, and Technology (IJEMST), 13*(1), 61-75. https://doi.org/10.46328/ijemst.4466

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International Journal of Education in Mathematics, Science and Technology

2025, Vol.13, No. 1, 61-75 https://doi.org/10.46328/ijemst.4466

# The Impact of Cognitive Flexibility and Classroom Engagement on High School Students' Creative Problem-Solving Skills

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## Article Info

***Article History***

Received:
05 February 2024
Accepted:
01 September 2024

***Keywords***

Creativity skills
Cognitive flexibility
Classroom engagement
Creativity
Problem solution



## Abstract

This study aims to analyze the impact of cognitive flexibility and classroom engagement levels on high school students' creative problem-solving skills. The participants are 341 tenth grade students from three different high schools, along with nine mathematics teachers who have been teaching these students for at least two years. Data analysis was conducted through sequential logistic regression and path analysis. Findings revealed that female students' achievement of a full score in solving a problem that requires creativity is lower compared to that of male students. Neither maternal nor paternal education level was a significant predictor of reaching a creative solution. Path analysis revealed that an increase in overall classroom engagement scores led to an increase in both creative problem-solving and success levels. However, when classroom engagement was the mediator variable, its direct positive significant predictive impact on creative problem-solving disappeared. In conclusion, academic achievement did not significantly predict creative problem-solving, and the significant effect of classroom engagement as a predictor disappeared when it is the mediator variable.


## Introduction

Mathematical thinking can be interpreted as the ability to employ mathematical techniques, concepts, and methods directly or indirectly in the problem-solving process (Henderson et al., 2002). People endeavor to solve problems in their daily lives (Blitzer, 2003). There is a need for mathematical thinking within the problem-solving process (Alkan et al., 2005). A problem is defined as a conflict in which an individual encounters obstacles hindering them from reaching a goal (Morgan, 1999). Olkun and Toluk (2003), on the other hand, define a problem situation as one that engenders the desire to solve it and reach a conclusion, does not currently have a solution, but can be solved by the individual using their existing knowledge, skills, and experiences to generate new solutions. Problem-solving behavior forms the basis for success in mathematics. Therefore, the problem-solving process is highly significant in both the teaching and learning of mathematics. Problem-solving is widely recognized as a scientific method in many fields, necessitating the demonstration of critical thinking, comprehension skills, creative and reflective thinking, as well as judgment and analytical behaviors. Today, the quality of an educational program is measured by how well individuals can achieve the targeted outcomes in mathematics classes, from preschool to university and beyond, and how effectively they can apply these skills in their lives, generate new ideas, and influence science and technology. In summary, a quality mathematics education is expected to produce individuals who can “solve problems and demonstrate creativity”. Mathematical problem-solving behavior, which has a significant role in our lives, has been categorized in various ways by different mathematicians.Lester (1994) suggests that problem-solving requires more than just recalling and executing simple operations or performing operations based on well-learned rules. He emphasizes that solving mathematical problems requires higher-order thinking skills that develop slowly over an extended period. According to the NCTM Standards (2000), good problems are described as those that arise from interactions with the environment, enable students to develop and apply solution proposals using their own knowledge, and create environments that allows discussion among students.

Kienel (1977) categorizes mathematical problem-solving skills into five. Type 1 problems can be solved by applying a rule, algorithm, or operation without demonstrating any higher-order thinking skills as there is a clear adherence to a rule, algorithm, or operation. In Type 2 problems, the rule, algorithm, or operation is known to the individual who solves the problem but cannot be fully expressed. Type 3 problems involve combining previously known rules, algorithms, or operations to solve the problem. That is to say, Type 1 and Type 3 problems can be solved directly by applying a rule, algorithm, or operation without requiring higher-level thinking skills. Type 4 problems are referred to as "everyday problems" where the focus is primarily on the analysis of mathematical content. To obtain Type 4 problems, Type 1 or Type 3 problems should be transformed into everyday life scenarios. Type 5 problems encompass all types of problems. To solve Type 5 problems, knowledge of rules, algorithms, and operations alone is not sufficient. Understanding the characteristics of the elements within the problem is also necessary. "Open-ended problems" or "challenging problems" are examples of Type 5 problems. When constructing solution scenarios for such problems, new ideas and cognitive leaps are required.

Additionally, Kienel (1977) emphasizes the necessity of fostering divergent or creative thinking in solving these types of problems, highlighting their requirement for creativity. In other words, they are the problem types which require creative thinking skills. Polya (1973) describes the failure to expose students to non-routine problems as an "unforgivable mistake," stating that doing so undermines students' imagination and judgment skills. There is a considerable amount of research in the literature on problem-solving. Some examples include the use of realistic mathematical modelling in mathematics problems to enhance problem-solving skills (Verschaffel et al., 1999), the influence of factors such as beliefs and attitudes on problem-solving (Aydın, 2014; Sezer, 2018), and the association between successful solutions in challenging problems and creativity (Kienel, 1977; Kiesswetter, 1983; Zimmermann, 1986).

Creativity can be defined in different ways. Zizhao (1999) defines creativity as a behavior involving freedom and relative originality. Kiesswetter (1983) defines it as a product of flexible thinking skills. According to Bishop (1976), creativity is a combination of two types of thinking: one logical (one-dimensional and language-based), and the other visual (multi-dimensional and intuitive). Although there is no standard definition of "creativity," it is an important concept within the scope of problem-solving in mathematics. Torrance (1981) suggests creativity is a combination of process methods that encompass the development of individual competence and the anticipation of problems. Resistance to change and a tendency not to embrace innovation are considered qualities that hinder a creative environment. In the development of creativity, it is also important for creative thinking to be encouraged by the environment in which the individual finds themselves, and for the necessary conditions to be provided (Sungur, 1997). Bartlet (1958) defines creativity as essentially losing the line and embarking on an experiential journey where differences prevail. The following are the characteristics of individuals who are creative (Turvey, 2006):

1. *Flexibility:* Being able to go beyond the existing norms by rejecting rules when qualities are in line with traditions and when ideas are innovatively organized based on available data, replacing conventional and expected qualities with creative processes.
2. *Fluency:* Embracing as many mental approaches as possible while solving problems.
3. *Elaboration:* Thoroughly analyzing problems while seeking solutions in a detailed manner.
4. *Tolerance for ambiguity:* Showing patience in seeking ways to reconcile conflicting solutions due to the clash of opposing ideas until delayed resolutions are concluded.
5. *Originality:* Diversifying paths to solutions by embracing ideas, norms, and values outside the norm through the process of reshaping previously set habits and rules.
6. *Wide range of interests:* An in-depth understanding of various perspectives over a single subject and having access to insights across multiple areas.
7. *Sensitivity:* Creating awareness of problems to redirect the attention of team members towards solutions and being generous in sharing successes as well as in solving problems.
8. *Curiosity:* Involving openness to innovative processes and requiring environmental awareness.
9. *Independence:* Embracing innovative thoughts within the use of individual strength and confidence.
10. *Reflection:* Considering values perceived or thought by others and evaluating the accuracy of ideas with empathy.
11. *Action:* Directing energy and desires towards a field through activities in line with thoughts and motivation.
12. *Concentration and determination:* Ability to initiate and sustain a task, assisting in achieving goals and objectives over a series of processes.
13. *Commitment:* Ensuring high motivation as a reflection of openness to satisfaction and development in subsequent processes before fulfilling responsibilities.
14. *Sense of humor:* Creating a lightening effect on responsibilities by perceiving elements of humor from life's contradictions and uncertainties.

Creativity and flexibility are the two essential elements that should be used in non-routine problem solving (Altun, 2005). Cognitive flexibility is a multidimensional process involving processing multiple pieces of information simultaneously, generating multiple ideas, considering alternatives, and altering or changing plans to adapt to a particular situation or context (Stevens, 2009). In this process, selecting knowledge to fit adaptively with the needs of understanding in a situation and decision-making is crucial; therefore, it depends on having a diversified repertoire of ways of thinking (Spiro, 1988), aiding individuals in finding adaptive responses to complex phenomena (Spiro et al., 2003). Similarly, Cañas et al. (2003) point out that cognitive flexibility is the human ability to adapt cognitive processing strategies to face new and unexpected situations. Another definition states that cognitive flexibility is an important characteristic that helps humans pursue challenging tasks and find novel and adaptable solutions to changing demands in everyday life (as cited in Ionescu, 2012). Thus, cognitive flexibility can be considered to involve a type of problem solving as well as trial and error, which is discussed as a type of fluid intelligence (Stevens, 2009). Therefore, cognitive flexibility is crucial for adaptive cognition, creative problem solving, and thinking out of the box (Peters & Crone, 2014).This study aims to examine the impact of cognitive flexibility and classroom engagement levels on high school students' creative problem-solving abilities and their ability to achieve creative solutions.

## Method

This research is a correlational study (Fraenkel et al., 2012) that analyses the relationships between creative problem solution, cognitive flexibility, and classroom engagement level.

### Participants

Participants are 341 high school students in the $10^{th}$ grade from three different state schools located in the Central Anatolia Region during the 2017-2018 academic year. All participants voluntarily participated in the research. The schools where the participants were enrolled were coded as School A, School B, and School C. Approximately 24% (N=83) of the $10^{th}$ grade students attend School A, approximately 38% (N=130) attend School B, and approximately 38% (N=128) attend School C. The sample formed by the voluntary participation of the students can be considered purposive sampling. Purposive sampling is created on the basis of working with a part of the population rather than the entire population (Şenol, 2012). In purposive sampling, researchers determine the characteristics of the individuals who will constitute the research population and reach out to individuals who fit these characteristics. Based on the researcher's knowledge of that population, individuals who can provide the best information for the research purpose are selected as participants (Christensen et al., 2014; McMillan & Schumacher, 2014).

### Data Collection Tools

*Cognitive Flexibility Scale*

Information on cognitive flexibility was obtained through the Cognitive Flexibility Scale, developed by Martin and Rubin, and adapted to Turkish by Çelikkaleli (2014). The scale was developed for adolescents who study at high school level. The scale consists of 12 items. The items are structured in six categories and Likert type. 2, 3, 6 and 10 are scored reversely. As a result of the factor analyses made during the Turkish version of the scale, the scale showed a single factor structure. The reliability coefficient for internal consistency is .74. The test-retest reliability is .98.

*Classroom Engagement Inventory*

The Inventory was developed by Wang, Bergin and Bergin and adapted to Turkish by Sever (2014). t form, the original inventory consisted of 24 items, but upon elimination of one item in the adaptation process, there remained 23 items. The inventory consisted of five sub-factors: “Cognitive Engagement”, “Affective Engagement”, “Behavioral Engagement-Compliance”, “Behavioral Engagement in Class”, and “Disengagement”. The reliability of the scale has been recalculated for this study and the Cronbach alpha coefficient of reliability is .93.

*Student Information Form*

The Student Information Form, which was used to gather information about the students' gender, maternal education level, paternal education level, and mathematics grades, was developed by the researcher and administered to 341 high school students ($10^{th}$ grade).

*Math Problem*

The math problem used in the study was selected by experts in Mathematics Education from previously administered PISA questions and specifically chosen for its requirement of creativity, known as the Oil Spill problem. The reliability of PISA questions is tested using the Rasch Delta model (OECD, 2013). Additionally, the fact that this problem was used in PISA assessments indicates a high level of internal validity. The reason for selecting this problem is its non-routine nature, requiring creative thinking to reach the correct solution, as standard and knowledge-based approaches are insufficient. It also requires judgment and is structured in a way that students need to develop a specific strategy to reach a solution. Furthermore, it involves self-assessment and requires cognitive flexibility (Turner & Adams, 2007).

*Rubric*

The solutions to the problems that require creativity were evaluated based on a rubric designed by PISA (2012). This rubric was supplemented with more detailed answers by mathematics education experts who hold Ph.D. and worked as faculty members. In addition, in terms of for content validity and reliability, the rubric was reviewed by a measurement and evaluation expert who also completed their Ph.D. and worked as a faculty member. In the preliminary stage of the study, the problem was administered to ten students, and this rubric was used by two separate researchers to score the students' responses. A 95% agreement was reached between the two researchers. After this practice, the rubric took its final form and was used for the application. In this study, students who received 2 points on the rubric for their responses to the math problem were determined as having a high level of creativity; those who received 1 point were evaluated as having a moderate level of creativity, and those who received 0 point were evaluated as having a low level of creativity skills.

**Data Analysis**

Data were analyzed using ordinal logistic regression analysis. Ordinal logistic regression analysis is used to identify the cause-effect relationship between explanatory variables (such as gender, maternal education, paternal education, engagement, cognitive flexibility, etc.) and the dependent variable (problem-solving in this study) when the dependent variable is categorical (Özdamar, 2013). Since the dependent variable (creativity level) was scored using a rubric, it is ordinal in nature.

The results were scored as "full score (2), half score (1), unsolved (0)" for creativity level. Whether gender, maternal education level, paternal education level, classroom engagement level, and cognitive flexibility level are explanatory variables for creativity level was determined using ordinal logistic regression analysis. IBM-SPSS was used for the analysis.

Based on goodness-of-fit statistics, it was determined that the complementary log-log linked ordinal logistic regression model was suitable ($p>0.05$). The relationship between the outcome dependent (problem-solving) and explanatory variables (gender, maternal and paternal education level, class attendance, cognitive flexibility level) was demonstrated by the obtained Cox and Snell $R^2$ and Nagelkerke $R^2$ values. It was determined that the complementary log-log linked ordinal logistic regression model was appropriate based on goodness-of-fit statistics ($p>0.05$).

When students' academic achievement level acts as a mediator variable, the impact of students' cognitive flexibility level and classroom engagement level on their problem-solving of mathematics tasks requiring creativity was examined. This examination was conducted using Path Analysis. Structural Equation Modelling (SEM) is a family of statistical methods used to model relationships between variables. The model in SEM can include both observed and latent variables. In SEM, models that evaluate the effects between observed variables without latent variables are possible. This describes the Path Analysis technique, the original member of the SEM family (Kline, 2016). The effect of the mediator variable, as indicated by Baron and Kenny (1986, p. 1176), was examined to have a full mediator effect, reducing the relationship between the explanatory variable and the dependent to zero.

**Ethical Approval**

This study was conducted with the approval of Uludağ University Social and Humanities Research and Publication Ethics Committee (Date of Approval: 29.09.2017/No:2017-14-4).

## Results

The participants were 341 tenth grade students from three different high schools. Among these students, 83 studied in School A, 130 in School B, and 128 in School C. In School A, 91.5% of students received 0 points for creative problem solving, 8.43% received 1 point, and 0% received 2 points. In School B, 62.3% of students received 0 points, 27.69% received 1 point, and 10% received 2 points for creative problem solving. In School C, 66.4% of students received 0 points, 18.75% received 1 point, and 14.8% received 2 points for creative problem solving. Additionally, of these 341 students, 70.96% received 0 points for creative problem solving, 19.64% received 1 point, and 9.38% received 2 points. It was observed that more than 50% of the students received 0 point, approximately 1/5 were in the group which received 1 point, and 1/10 were in the group receiving 2 points.

**The Impact of Students' Gender, Parental Education Level, Achievement, Cognitive Flexibility, and Classroom Engagement on Creative Problem Solving**

The Impact of students' gender, parental education level, achievement, cognitive flexibility, and classroom engagement on creative problem solving was analyzed using ordinal logistic regression. Based on goodness-of-fit statistics, it was determined that the complementary log-log linked ordinal logistic regression model was appropriate ($p>0.05$). From the Cox and Snell $R^2$ and Nagelkerke $R^2$ values, it was found that there is a relationship between the dependent variable (problem-solving) and the explanatory variables (gender, parental education level, classroom engagement, cognitive flexibility level). Predictions made for the ordinal logistic regression can be seen in Table 1.

Table 1. The Relationships in the Ordinal Logistic Regression Model[1]

| | | **Prediction** | **Standard Error** | **Wald** | **p** |
|---|---|---|---|---|---|
| Cut-off Values | Unsolved, “0” | 1.951 | 1.721 | 1.285 | 0.257 |
| | Half-Score “1” | 3.434* | 1.729 | 3.947 | **0.047** |
| Explanatory Variables | Academic Achievement | 0.009 | 0.008 | 1.316 | 0.251 |
| | Flexibility | -0.029 | 0.025 | 1.419 | 0.234 |
| | Affective Engagement | 0.030 | 0.031 | 0.960 | 0.327 |
| | Behavioral Engagement Compliance | 0.061 | 0.060 | 1.029 | 0.310 |
| | Behavioral Engagement in Class | 0.029 | 0.055 | 0.273 | 0.601 |
| | Cognitive Engagement | 0.015 | 0.033 | 0.199 | 0.656 |
| | Disengagement | 0.011 | 0.056 | 0.035 | 0.851 |
| | Gender (Female) | -0.730** | 0.273 | 7.151 | **0.007** |
| | Maternal Educational Level (Primary) | 0.105 | 0.488 | 0.046 | 0.830 |
| | Maternal Educational Level (Secondary) | 0.275 | 0.492 | 0.312 | 0.576 |
| | Maternal Educational Level (High School) | 0.412 | 0.454 | 0.826 | 0.363 |
| | Paternal Educational Level (Primary) | -0.072 | 0.974 | 0.006 | 0.941 |
| | Paternal Educational Level (Secondary) | -0.606 | 0.979 | 0.383 | 0.536 |
| | Paternal Educational Level (High School) | -0.558 | 0.930 | 0.360 | 0.548 |
| | Paternal Educational Level (Secondary) (University) | 0.668 | 0.935 | 0.510 | 0.475 |

[1]Among the explanatory variables, "males" were chosen for gender, "university" for maternal education level, and "postgraduate" for paternal education level as the reference groups, and comparisons were made accordingly *p<.05 **p<.01.

In Table 1, obtaining a half score in creative problem-solving is as significant as well as obtaining a full score ($p<.05$). However, leaving the problem unsolved is not a significant variable. Among the explanatory variables, the sub-dimensions of classroom engagement and cognitive flexibility, which are continuous variables, are not significant variables in problem-solving (p>.05). Gender among the explanatory variables is a significant variable (p<.05). Being female is a negative predictor for obtaining a full score compared to being male. The likelihood of females obtaining a full score is lower than males. Maternal and paternal education levels among the explanatory variables are not significant predictors (p>.05).

## The Impact of Academic Achievement as a Mediator, Cognitive Flexibility, and Classroom Engagement on Creative Problem Solving

The impact of students' cognitive flexibility and classroom engagement levels on their ability to solve problems creatively when the academic achievement level of students serves as a mediator variable. This analysis was conducted using Path Analysis. The path diagram for the analysis is demonstrated in Figure 1.

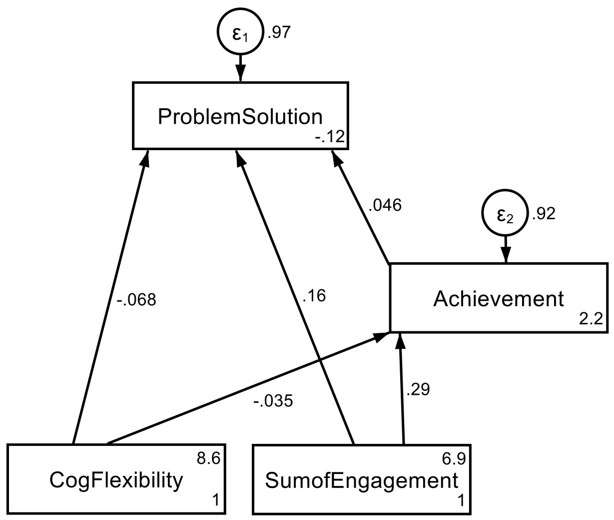


Figure 3. Path Modelling

The model fit indices for the Path Analysis were calculated as follows: CFI=.972, TLI=.968, RMSEA=.071. These values fall within the acceptable range, considered as excellent according to the literature (Anderson & Gerbing, 1984; Bentler, 1990; Hooper et al., 2008; Hu & Bentler, 1999; Kline, 2005; Marsh et al., 1988; Tabachnick & Fidell, 2013, Vieira, 2011). The regression coefficients and direct and indirect effects of the model are provided in Table 2.

In direct effects, classroom engagement is a significant predictor with a positive effect on creative problem-solving (p<.05). Similarly, classroom engagement is also a significant predictor with a positive effect on academic achievement (p<.05), which indicates as classroom engagement increases, both creative problem-solving and academic achievement increase. In indirect effects, neither cognitive flexibility nor classroom engagement has a significant effect on creative problem-solving when achievement serves as a mediator. In other words, the positive significant predictive power of classroom engagement on creative problem-solving as a direct effect disappears when achievement becomes a mediator variable. Academic achievement, by eliminating the directly significant effect as stated by Baron and Kenny (1986, p.1176), demonstrates the true mediator variable effect. In summary, academic achievement does not have a significant predictive impact on creative problem-solving, and the significant effect of classroom engagement as a predictor disappears when academic achievement serves as a mediator.

Table 2. Predictions in the Path Analysis Model

| **Variables** | **Coefficient** | **Standard Error** | **z** | **p** |
|---|---|---|---|---|
| ***Direct Effect*** | | | | |
| Achievement → Problem Solution | 0.002 | 0.002 | 0.83 | 0.407 |
| Cognitive Flexibility → Problem Solution | -0.008 | 0.006 | -1.22 | 0.221 |
| Classroom Engagement Total Score → Problem Solution | 0.009 | 0.003 | 2.82 | **0.005** |
| Cognitive Flexibility → Achievement | -0.110 | 0.173 | -0.64 | 0.522 |
| Classroom Engagement Total Score → Achievement | 0.474 | 0.089 | 5.32 | **0.000** |
| ***Indirect Effect*** | | | | |
| Cognitive Flexibility → Achievement → Problem Solution | -0.001 | 0.001 | -0.51 | 0.612 |
| Classroom Engagement Total Score → Achievement → Problem Solution | 0.001 | 0.001 | 0.82 | 0.412 |

## Conclusion

The findings revealed that in creative problem solving, female students are less likely to obtain full scores compared to that of male students. Maternal and paternal education levels are not significant predictors for creative problem solving. In the related literature, there are studies that are in line with these results (Öğretmen & Doğan, 2004; Özdemir, 2013). However, the literature also indicates that different results which identify females as more creative than males (Ayverdi et al., 2012; Gülel, 2006) and males as more cognitively flexible than females (Öncü, 2003), gender does not create differences in creativity (Baer & Kaufman, 2008; Temizkalp, 2010; Topoğlu, 2015), and some studies find that creativity and gender variables predict academic achievement and have significant relationships between them (Naderi et al., 2009; 2010). Nakano et al. (2021) examined 133 publications on creativity in the context of gender between 1975 and 2020 in their systematic review. 45% of the studies found results in favor of women and 23% in favor of men. In 31% of the studies, different results were shown in favor of women or men depending on the content of creativity.

In the ordinal logistic regression analysis, the predictiveness of the total score obtained from the five subscales of the classroom engagement inventory was tested on creative problem solving, while in path analysis, the predictiveness of the total score of the classroom engagement inventory on creative problem solving was tested without considering the subscales of the inventory. According to the results of ordinal logistic regression, the subscales of classroom engagement were not significant for creative problem solving, whereas path analysis showed that if the total score of classroom engagement increases, both the likelihood of creative problem-solving and academic achievement increase. The positive significant predictive effect of classroom engagement on creative problem-solving as a direct effect disappeared when achievement served as a mediator variable. In summary, academic achievement did not have a significant effect on creative problem-solving, and the significant effect of classroom engagement as a predictor disappeared when academic achievement served as a mediator.

The literature that focus on the relationship between academic achievement and creativity can yield different results. Studies have shown low correlation between these two variables (Erdoğdu, 2006; Kara, 2011), positive and significant correlation (Anwar et al., 2012; Ayverdi et al., 2012; Florence et al., 2015; Gautam, 2017; Jenaabadi et al., 2014; Naderi et al., 2010; Nami et al., 2014; Niaz et al., 2000), strong correlation (Yeh, 2004), no correlation (Balgiu & Adîr, 2013; Olatoye et al., 2010; Tatlah et al., 2012), and negative correlation (Olatoye et al., 2010). Kattou et al. (2012) identified a positive relationship between mathematical creativity and academic achievement. According to Gautam (2017), academic achievement is positively and significantly correlated with various dimensions of creative thinking (flexibility, fluency, originality, and overall creativity). Chauhan and Sharma (2017) found that creativity is an important variable as a predictor of academic achievement. Gajda et al. (2017), in their meta-analysis study on the relationship between creativity and academic achievement, revealed a positive and moderate correlation between creativity and achievement. Bicer et al. (2021) conducted a meta-analysis examining studies between 1965 and 2018. According to the results of this research, it was determined that there was a moderate, positive and significant relationship between mathematics achievement and creativity. In addition, according to this research, it was determined that this relationship was stronger when mathematical creativity was examined specifically instead of general creativity.

The relationship between creativity and cognitive flexibility is also one of the research focuses in literature. Related studies have found a positive relationship between creativity and cognitive flexibility (Chen et al., 2014), indicating that flexible thinking predicts creative performance, the ability to generate new ideas, and the ability to find multiple ways to use an idea (Barbey et al., 2013; De Dreu et al., 2011; De Dreu, 2007). Additionally, the literature suggests that cognitive flexibility is associated with creative performance (Guilford, 1967, as cited in Lim, 2013); individuals with higher levels of cognitive flexibility can more effectively use their abilities and are aware of multiple solutions when faced with a problem (Hill, 2008). In the study conducted by Li et al. (2023), cognitive, emotional, and behavioral engagement were identified as effective factors for improving students' higher-order thinking skills.

Additionally, increasing students' emotional engagement enhances the positive relationships between cognitive engagement, computational thinking, and creative thinking. However, when students' behavioral engagement levels increase, the positive relationship between cognitive engagement and critical thinking, as well as the positive relationship between emotional engagement and problem-solving and critical thinking, decrease. In the meta-analysis conducted by Santana et al. (2022), it was shown that cognitive flexibility is a variable that has a significant effect on mathematics performance. In addition, this effect was found to be stronger in younger children.

## Notes

This article is a part of the doctoral dissertation titled "Student and Teacher Characteristics Affecting Creative Problem Solving Skills of Tenth Grade Students" conducted under the supervision of Prof. Dr. Murat Altun.

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