**Journal on Mathematics Education**
Volume 15, No. 1, 2024, pp. 253-276

# Mathematics learning orientation: Mathematical creative thinking ability or creative disposition?

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Received: 15 September 2023 | Revised: 19 November 2023 | Accepted: 1 December 2023 | Published Online: 2 January 2024


## Abstract

Mathematical creative thinking skill often becomes the orientation of mathematics learning, aiming to enhance students' creativity in mathematics. Recognizing that creativity encompasses the capacity for thinking creatively and creativity disposition is essential. Building on this conceptual foundation, the primary objective of this study is to develop a comprehensive model illustrating the relationship between students' aptitude for mathematical creative thinking and their creative disposition. The research methodology employed in this study aligned with the framework of cause-and-effect analysis. The study cohort consisted of 36 students, carefully selected by a cluster random sampling technique. The research instruments included a mathematical creative thinking ability assessment and a creative disposition scale. The data was analyzed using the Non-Recursive Structural Equation Modeling. The results showed the reciprocal cause-and-effect dynamic between mathematical creative thinking ability and creative disposition, exhibiting a mutually influential relationship with determination coefficients of 21.83% and 21.05%. This shows that mathematical creative thinking ability is better at explaining mathematical creative disposition than mathematical creative disposition explaining mathematical creative thinking ability, with a relatively small difference (0.78%). This study also concluded that an optimal approach to mathematics pedagogy entails a balanced and simultaneous focus on nurturing mathematical creative thinking ability and disposition.

**Keywords**: Creativity, Mathematical Creative Disposition, Mathematical Creative Thinking Ability, Non-Recursive Structural Equation Modeling

**How to Cite**: Ibrahim, Khalil, I. A., & Prahmana, R. C. I. (2024). Mathematics learning orientation: Mathematical creative thinking ability or creative disposition?. *Journal on Mathematics Education, 15*(1), 253-276. http://doi.org/10.22342/jme.v15i1.pp253-276

Creativity is a 21st-century skill, according to the 21st Century Skills Partnership (21st Century Skills Map, 2012). Creativity in solving mathematical problems holds a pivotal role in determining the problem's focal point, linking its constituent elements, and facilitating the exploration of various solutions for problem-solving (de Vink et al., 2022; Schindler & Lilienthal, 2022; Utemov et al., 2020). The study's findings convey that mathematical creativity helps create space for students to analyze mathematical problems and reach a higher level of mathematical problem-solving ability (Sinniah et al., 2022). Students' engagement in solving mathematical problems characterized by many solutions contributes substantively to cultivating and enhancing their creativity (Ibrahim & Widodo, 2020; Shaw et al., 2022), for example, student flexibility (Bevan & Capraro, 2021). The pedagogical approach in mathematics instruction necessitates reconsidering traditional student practices involving repetitive restatements, formulaic utilization, and procedural adherence. The curtailment of these habits becomes paramount for elevating student creativity (Andrade et al., 2020; Conner et al., 2014; Powell et al., 2013). Embedding students in mathematical learning experiences that enhance creative thinking augments their creative capacity and concurrently improves their overall academic achievement (Jonsson et al., 2022; Niu et al., 2022).

Fostering students' mathematical creativity is critical for realizing their future aspirations (Lubart et al., 2013; Vu et al., 2022). Creativity in mathematics is defined as the ability to solve various mathematical problems (Isyrofinnisak et al., 2020). The core of creativity is the capacity to engender novel ideas and inventive solutions throughout the problem-solving process (Ovando-Tellez et al., 2022). Beyond being confined to novel ideas, creativity is also intricately tied to new and valuable behaviors (Fiori et al., 2022). Within cognition, creative thinking is construed as a form of mental activity capable of yielding solutions that deviate from pre-existing paradigms in their diversity, uniqueness, and originality (Ramdani et al., 2022). Creative thinking encompasses four dimensions: fluency, flexibility, elaboration, and originality (Bulut et al., 2022; Chermahini & Hommel, 2012; Garcia & Mukhopadhyay, 2019; Schindler & Lilienthal, 2022; Setiyani et al., 2022; Tan et al., 2021). In parallel, creativity also manifests as a behavioral orientation characterized by the willingness to embrace risks, embrace challenges, nurture curiosity, and indulge in imaginative pursuits (Lubart et al., 2013; Rabi & Masran, 2016). This idea implies that creativity inherently embodies creative thinking and creative behavior tendencies. This tendency for creative behavior accompanies creative thinking in the context of creativity and is commonly called the creative disposition (Fiori et al., 2022; Lubart et al., 2013; Sumarmo et al., 2012).

Within the context of mathematics education, the cognitive aspect of creativity is intricately intertwined. Specifically, when students address mathematical problems or navigate mathematical scenarios, the dimensions of fluency, flexibility, elaboration, and originality come to the fore. Fluency is defined as the ability to answer or solve problems or respond to mathematical situations correctly, while flexibility is defined as the ability to answer or solve problems or respond to mathematical situations in various ways (Bulut et al., 2022; Grégoire, 2016; Schindler & Lilienthal, 2022; Toheri et al., 2020). Elaboration is defined as the ability to answer or solve problems or respond to mathematical situations in detail. In contrast, originality is defined as the ability to answer or solve problems or respond to mathematical situations using language, methods, or non-routine and relevant ideas (Bulut et al., 2022; Grégoire, 2016; Schindler & Lilienthal, 2022; Tan et al., 2021; Toheri et al., 2020; Türkmen, 2015).

Creativity related to behavioral tendencies in learning mathematics, aspects of risk-taking, challenge, curiosity, and imagination are observed when students respond to mathematical situations encountered in the learning (Lubart et al., 2013; Rabi & Masran, 2016). Risk-taking is defined as the behavioral tendency to be ready to fail, propose conjectures, and defend opinions. In contrast, fondness for challenges is defined as the behavioral tendency to seek out a plethora of potential solutions actively, resourcefully explore materials to solve problems, and love mathematical challenges (Grégoire, 2016; Rabi & Masran, 2016). Curiosity is defined as the behavioral tendency to question, engage in novel activities, be interested in mysteries, an attraction to puzzles, and eagerness to embrace novel experiences (Aizikovitsh-Udi & Amit, 2011; Daher et al., 2021; Ennis, 1993; Herwin & Nurhayati, 2021; Kashdan et al., 2018; Suhirman et al., 2021; Tan et al., 2021). Imagination is defined as a behavioral inclination encompassing the capacity to conjure and fashion mental imagery, envision scenarios that transcend existing realities and traverse domains that extend beyond the sensory perception (Jagals & van der Walt, 2019; Kanoknitanunt et al., 2021; Turan & Dişçeken, 2019).

The cognitive and affective domains are interrelated in the process of solving problems or responding to a problem situation, similarly critical thinking ability and critical thinking disposition (Aizikovitsh-Udi & Cheng, 2015; Álvarez-Huerta et al., 2022; Fikriyatii et al., 2022). Similarly, for creative thinking and creative disposition, creativity is realized due to creative thinking and creative disposition (Fiori et al., 2022; Sumarmo et al., 2012). This provides the basis for the assumption that student creativity in learning mathematics can be realized from creative thinking combined with a creative disposition. The manifestation of student creativity in learning mathematics will appear when students face mathematical problems or situations to solve.

Mathematical creativity is one of the focus objectives of learning mathematics along with critical thinking, disposition, and problem-solving skills (Kalelioğlu & Gülbahar, 2014; Rahmawati & Ibrahim, 2021) because creativity is essential for students to solve mathematical problems (de Vink et al., 2022; Elgrably & Leikin, 2021; Powell et al., 2013; Shaw et al., 2022). Some studies even suggested integrating mathematical creativity skills into the content of mathematics textbooks (Khalil & Alnatheer, 2020). The mathematical problems students must solve are closely linked to the mathematics topics, including relations and functions, as in the Indonesian curriculum for junior high schools (Setiyani et al., 2020).

Relation and function in Indonesia's junior high school curriculum are grouped within the algebra (Setiyani et al., 2020). Relation and function are crucial for students to understand as they are prerequisite topics to understand calculus or algebra at higher levels of schooling (Bardini et al., 2014). This signifies that the relations and functions students study possess varying complexity and depth, corresponding to their academic level. Therefore, students must progressively advance their comprehension of relations and functions.

Several prior research studies have endeavored to enhance students' comprehension of the relations and functions (Bardini et al., 2014; Ibrahim et al., 2021; Ibrahim & Widodo, 2020; Kurniati et al., 2015; Oliveira et al., 2021; Saraswati et al., 2016). This endeavor for understanding enhancement predominantly focuses on the cognitive domain. Nonetheless, it is noteworthy that advancements within the cognitive domain are optimally complemented by corresponding advancements within the affective domain (Chong et al., 2019; Ozkal, 2019; Rahmawati & Ibrahim, 2021; Tang & Hew, 2022; Wu et al., 2022). Similarly, efforts toward nurturing mathematical creativity are also rooted in an orientation toward developing the cognitive domain (Bicer et al., 2020; Ibrahim & Widodo, 2020; Jonsson et al., 2020; Kadir et al., 2016; Utemov & Masalimova, 2017).

As mentioned earlier, creativity thrives when cognitive and emotional aspects reinforce each other. This means that student's ability to think creatively in math and their disposition for creative thinking are connected and influence each other. Understanding how these linked aspects can help design math lessons that boost students' creativity. With this discernment, the interventions introduced within the framework of mathematics instruction are likely to yield a constructive impact on nurturing student creativity. This, in turn, bears implications for the optimization of mathematics learning accomplishments in alignment with curriculum objectives, consequently supporting the realization of students' future aspirations (Lubart et al., 2013; Ovando-Tellez et al., 2022; Vu et al., 2022).

This research is essential to understand the relationship model between mathematical creative thinking ability and creative disposition within relations and functions. Structural Equation Modeling (SEM) can provide a detailed and comprehensive insight into the structure of this relationship model. It attempts to fill the gap in studies regarding the relationship between creative mathematical thinking abilities and creative dispositions using SEM, as well as the initial stride in enhancing students' mathematical creativity. Next, a potential resolution can be proposed by implementing a specific approach to mathematics education based on the insights from the study.

Consequently, the primary objective of this study is to identify a model explaining the relationship between students' mathematical creative thinking ability and their mathematical creative disposition. The findings of this study hold the potential to refine mathematics education, fostering the development of students' mathematical creativity, particularly in algebra. This enhancement is envisioned through formulating mathematics instructional approaches informed by the established relationship model structure's insights that represent the relationship between students' mathematical creative thinking ability and their mathematical creative disposition, thereby optimizing the learning experience.

## METHODS

This research has a quantitative paradigm and employed a cause-and-effect relationship research design (Creswell, 2012; Creswell & Creswell, 2018; Gay et al., 2012). This paradigm and design were chosen for their capacity to analyze the relationship between mathematical creative thinking and creative disposition variables, encompassing the reciprocal influence of these variables in a non-manipulated context based on quantitative data analysis. This study's measurement of mathematical creative thinking was explicitly linked to algebra, precisely relation and function material. In contrast, the measurement of mathematical creative disposition was not directly associated with mathematical topics but was inherently linked to the context of mathematics learning.

The population of this study was all Year 8 students at one of the public junior high schools in Bandung, Indonesia, 360 students, to be precise. The students were divided into ten classes, each consisting of 36 students. The samples were 36 students selected and taken using the cluster random sampling technique. In the first step, three subjects were randomly selected from each class to obtain thirty subjects. In the second step, six classes were randomly selected from the ten classes, and then one subject was randomly selected from the six classes. A sample size above 30 is sufficient for a cause-and-effect relationship research design (Creswell, 2012; Gay et al., 2012); 10% of the population has a size of 100 to 1000 (Gay et al., 2012).

This research employed two main instruments: the Mathematical Creative Thinking Ability Test (MCvTAT) and the Mathematical Creative Disposition Scale (MCvDS), both administered to the samples. The MCvTAT comprised seven open-ended questions about relations and functions. Students' creative thinking ability was evaluated based on the dimensions of fluency, flexibility, elaboration, and originality (Bulut et al., 2022; Chermahini & Hommel, 2012; Grégoire, 2016; Schindler & Lilienthal, 2022; Tan et al., 2021; Toheri et al., 2020; Türkmen, 2015). Among the seven items on the MCvTAT, two pertained to fluency, one addressed flexibility, three evaluated elaboration, and one was originality-related. Meanwhile, the items of the MCvDS aligned with the aspects of risk-taking courage, liking challenges, curiosity, and imagination dimensions (Daher et al., 2021; Ennis, 1993; Grégoire, 2016; Herwin & Nurhayati, 2021; Jagals & van der Walt, 2019; Kanoknitanunt et al., 2021; Kashdan et al., 2018; Suhirman et al., 2021; Turan & Dişçeken, 2019). The MCvDS consisted of 14 statement items: three items for risk-taking courage, three items for liking challenges, five items for curiosity, and three items for imagination. Notably, the MCvTAT and MCvDS instruments underwent validation by five experts within their respective domains. This validity is calculated using Aiken's V coefficient value formula created by Lewis R Aiken (Aiken, 1980, 1985). The expert assessment shows that Aiken's V coefficient value for each question item and statement on the two instruments exceeds the critical value limit with five rating categories and a probability of 1% or 5% so that the validity is concluded that each item is valid. The construct validity and estimates of the reliability of the instrument construct were obtained from the research sample data analysis results. The results of the data analysis are presented in the results and discussion section.

The data in this study consisted of two categories: students' mathematical creative thinking ability and mathematical creative disposition. As derived from measurement outcomes, data regarding students' mathematical creative thinking ability was interval data. Conversely, data about students' mathematical creative disposition, initially of an ordinal nature, were transformed into interval data before analysis. The procedure for changing ordinal data is converted into interval data using the method of successive intervals, which Thurstone developed in the 1950s. This procedure is recommended for considering possible inequalities in the widths of the intervals on the psychological scale continuum (Edwards, 1957). The data analysis process unfolded through two phases. In the initial phase, descriptive statistics were applied, encompassing computations of the mean, variance, standard deviation, maximum score, and minimum score for each data group. This stage aimed to provide a comprehensive overview of the data distribution. Subsequently, the data underwent inferential statistical analysis utilizing Structural Equation Modeling (SEM), employing the Non-Recursive Model using Linear Structural Relationship (LISREL) software developed by Karl Jöreskorg and Dag Sörbom from Uppsala University. The rationale for selecting the Non-Recursive Model stems from the prediction that the two variables under investigation exhibit a reciprocal cause-and-effect relationship or lack a clearly defined causal direction (Bagozzi, 1980; Felson & Bohrnstedt, 1979; Jöreskog & Sörbom, 1993; Vacca & Zoia, 2019; Young, 1998; Yu & Chen, 2021).

## RESULTS AND DISCUSSION

Table 1 presents descriptive statistics of mathematical creative thinking ability (MCvTA) and mathematical creative disposition (MCvD) for 36 students.

**Table 1.** Descriptive statistics of students' mathematical creative thinking ability (MCvTA) and mathematical creative disposition (MCvD)

| Variable | Mean | Standard Deviation | Maximum Score | Minimum Score |
|---|---|---|---|---|
| MCvTA | 47.42 | 26.82 | 94.00 | 6.00 |
| MCvD | 66.13 | 12.03 | 88.39 | 38.21 |

It reveals that the mean for MCvD surpasses 50% of the ideal score (100). In contrast, MCvD mean score is also notably higher than the MCvTA score. Moreover, the standard deviation of both variables indicates that the dispersion of MCvTA score data is more extensive than that of MCvD data. In light of these computed means and standard deviations, it is apparent that students' MCvD scores are comparatively higher than their MCvTA scores. Furthermore, the distribution of students' MCvD scores is more uniform than their MCvTA scores. Notably, the range between the highest and lowest MCvTA scores demonstrates a significantly wider variation than that observed in the MCvD scores. This discrepancy implies exceptionally high and extremely low MCvTA scores among the sample group, a pattern not as pronounced in the MCvD scores.

Figure 1 presents the mean percentage of students' MCvTA scores for each dimension compared to their ideal scores.

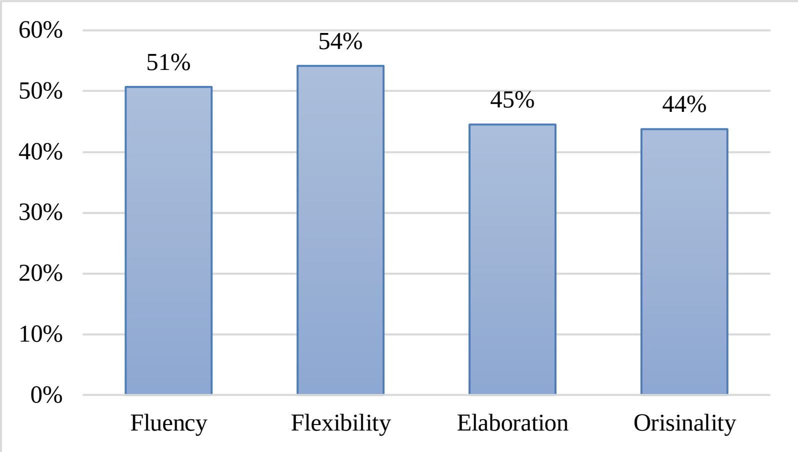


**Figure 1.** Mean percentage of students' MCvTA scores in comparison to their ideal score for each dimension

It indicates that the items for each dimension seem to have a comparable difficulty level, with the respondents achieving about 50% of the ideal score for each dimension. Students' MCvTA on relations and functions for each aspect can be interpreted as relatively equal. However, the flexibility dimension shows the highest achievement in MCvTA, and the originality dimension has the lowest achievement in MCvTA. Figure 1 shows that the mean score of every dimension is below 55% of the ideal score, or the overall students' MCvTA on relation and function falls under the low criteria.

Figure 2 illustrates the mean percentage of students' MCvD scores compared to the ideal score for each aspect.

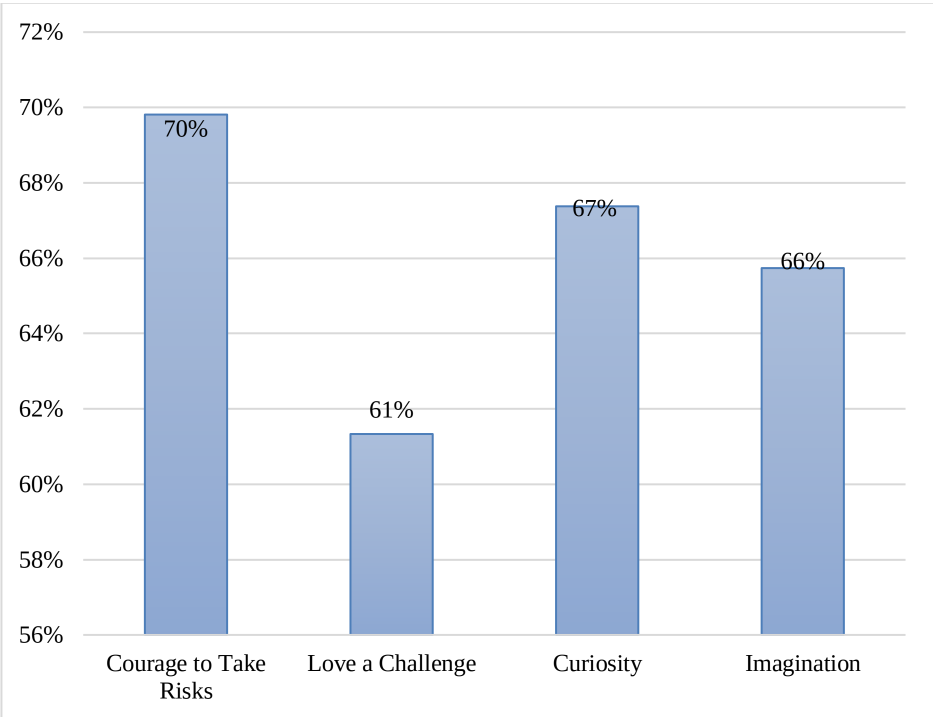


**Figure 2.** Mean percentage of students' MCvD scores in comparison to the ideal score for each aspect

It illustrates students' MCvD scores across various aspects, indicating an average range between 60% and 70% of the ideal score. This observation suggests that students' MCvD scores across these aspects are relatively uniform. Nonetheless, a discernible pattern emerges where students exhibit a tendency towards risk-taking behaviors, albeit a relatively less favor towards embracing challenges. Figure 2 shows that the mean of each aspect falls below 70% of the ideal score, signifying that students' MCvD scores are classified as moderate overall.

The data analysis results from 36 respondents reveal a product-moment correlation coefficient of 0.421 between students' MCvTA and MCvD (p=0.011). This outcome signifies the presence of a significant relationship between students' MCvTA and MCvD scores. However, it is essential to note that this correlation does not necessarily imply a reciprocal causal relationship between the two variables. Assessing a reciprocal causal relationship between students' MCvTA and MCvD requires Structural Equation Modeling (SEM), a Non-Recursive Model, which was done using LISREL software. This test commenced by calculating the correlation matrix among the observed variables. The correlation matrix between the observed variables of MCvTA and MCvD is displayed in Table 2.

**Table 2.** Correlation matrix between the observed variables of MCvTA and MCvD

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MCvTA** | | | | | | | | | |
| | **Fluency** | 1.000 | | | | | | | |
| | **Flexibility** | 0.422 | 1.000 | | | | | | |
| | **Elaboration** | 0.501 | 0.319 | 1.000 | | | | | |
| | **Originality** | 0.695 | 0.259 | 0.652 | 1.000 | | | | |
| **MCvD** | | | | | | | | | |
| | **Courage to Take Risks** | 0.439 | -0.211 | 0.370 | 0.461 | 1.000 | | | |
| | **Love a Challenge** | 0.214 | 0.038 | 0.285 | 0.262 | 0.261 | 1.000 | | |
| | **Curiosity** | 0.463 | 0.003 | 0.184 | 0.251 | 0.592 | 0.456 | 1.000 | |
| | **Imagination** | 0.471 | 0.177 | 0.347 | 0.357 | 0.611 | 0.524 | 0.649 | 1.000 |

The correlation matrix produces the coefficient of determination, indicating the ability of predictors to explain the dependent variable (Chicco et al., 2021; Jöreskog & Sörbom, 1993; Ozer, 1985; Wright, 1921; Zhang, 2016). MCvTA is a predictor of its dimensions, and MCvD is a predictor of its aspects. MCvTA can explain each of its dimensions by its coefficient of determination, and MCvD can similarly explain each of its aspects by its coefficient of determination. In addition, MCvTA and MCvD alternately became the predictor and dependent variables. In other words, MCvTA can explain MCvD by the coefficient of determination and vice versa. Table 3 displays the coefficient of determination for each of these variables.

Table 3 shows that authenticity is one dimension that can be explained by MCvTA with the largest determination coefficient (0.7171), meaning that MCvTA can explain the variance in authenticity dimension by 71.71%. Meanwhile, flexibility has the lowest smallest determination coefficient (0.2148), meaning that MCvTA can only explain the variance of flexibility by 21.48%. Table 3 also shows that the imagination aspect of MCvD has the most significant determination coefficient (0.6889), meaning that MCvD can explain the variance in this aspect by 68.89%. Meanwhile, loving a challenge has the smallest determination coefficient (0.3436). In other words, MCvTA can explain the variance of this aspect by 34.36%. In addition, Table 3 shows that MCvTA is better at explaining MCvD than MCvD explaining MCvTA, with a relatively small difference (0.78%).

**Table 3.** Coefficient of determination of the predictor and dependent variable of MCvTA dimensions and MCvD aspects

| Predictor | Dependent Variable | Coefficient of Determination (R Square) |
|---|---|---|
| MCvTA | Fluency | 0.6425 |
| MCvTA | Flexibility | 0.2148 |
| MCvTA | Elaboration | 0.4998 |
| MCvTA | Originality | 0.7171 |
| MCvD | Courage to Take Risks | 0.4968 |
| MCvD | Love a Challenge | 0.3436 |
| MCvD | Curiosity | 0.5108 |
| MCvD | Imagination | 0.6889 |
| MCvTA | MCvD | 0.2183 |
| MCvD | MCvTA | 0.2105 |

Figure 3 presents the standardized solution path diagram output based on the correlation matrix in Table 3.

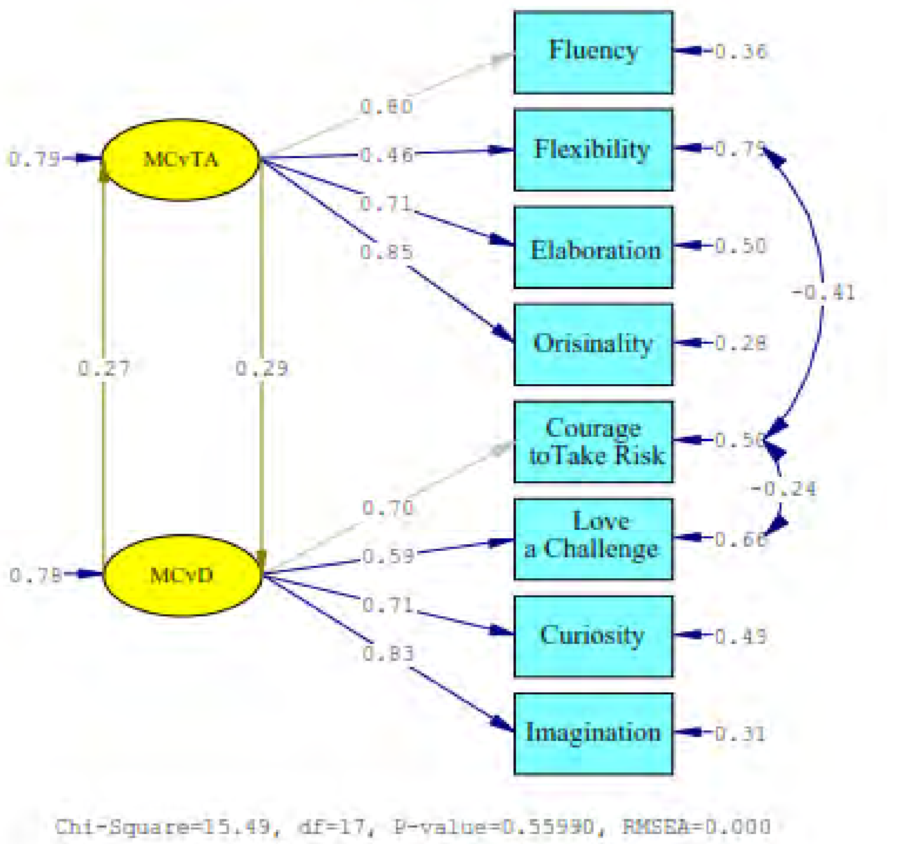


**Figure 3.** Standardized solution path diagram of non-recursive structural model of MCvTA and MCvD

It is a standardized solution path diagram of a non-recursive structural model of the MCvTA and MCvD. The model was revised based on the output of the previous analysis results. Figure 3 shows that the standardized loading factors of each dimension of MCvTA and each aspect of MCvD are above 0.4. This finding indicates that all dimensions of MCvTA and all aspects of MCvD were retained or none removed from the measurement model (Guadagnoli & Velicer, 1988; Kerlinger, 1967; Wijayanto, 2015; Ximénez, 2009).

Figure 4 presents the t-values of the path diagram based on the correlation matrix in Table 2.

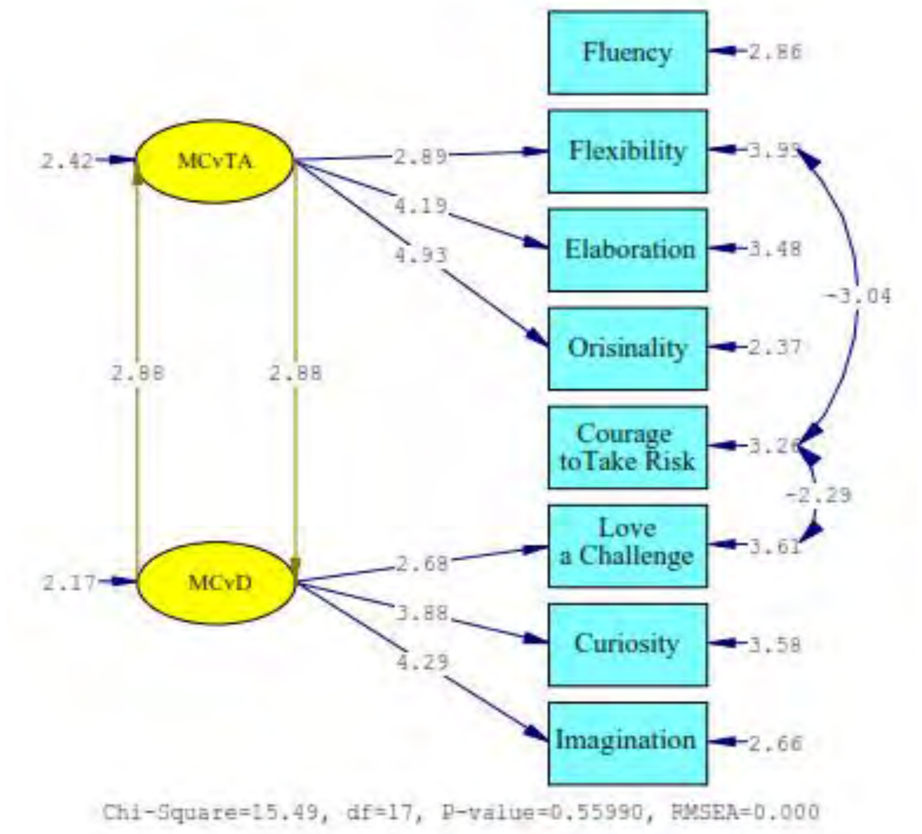


**Figure 4.** T-Values path diagram of the non-recursive structural model of MCvTA and MCvD

It shows all t-values are above 1.96, which is the critical value for the 95% confidence level in the normal distribution, and it is used as a critical value in SEM (Cangur & Ercan, 2015; Chan & Lay, 2018; Chuenban et al., 2021; Jöreskog & Sörbom, 1993; Kornpitack & Sawmong, 2022; Wijayanto, 2015; Yu & Chen, 2021). Thus, all estimated loading factors in the Non-Recursive Structural Model of the MCvTA and MCvD are significant and can be used for the measurement model.

Figures 3 and 4 show that the Non-Recursive Structural Model of MCvA and MCvD has met the criteria for good model fit, indicated by the p-value and Chi-Square ($\chi^2$) above 0.05 and Root Mean Square Error Approximation (RMSEA) below 0.05 (Bagozzi, 1977; Cangur & Ercan, 2015; Chuenban et al., 2021; Fornell & Larcker, 1981; Hsu et al., 2006; Jöreskog & Sörbom, 1993; Kornpitack & Sawmong, 2022; Schermelleh-Engel et al., 2003; Wijayanto, 2015). The structural model indicates that MCvTA and MCvD have a reciprocal or non-recursive causal relationship. This reciprocal causal relationship between MCvTA and MCvD also means that MCvD can explain the variance that occurs in MCvTA by the coefficient of determination and vice versa (Chicco et al., 2021; Jöreskog & Sörbom, 1993; Ozer, 1985; Wright, 1921; Zhang, 2016).

The construct reliability (CR) and variance extracted (VE) values of the MCvTA and MCvTA Non-Recursive Structural Models are presented in Table 4.

**Table 4.** Construct reliability and variance extracted from the MCvTA and MCvD measurement model

| Variable | Construct Reliability (CR) | Variance Extracted (VE) | Conclusion |
|---|---|---|---|
| MCvTA | 0.81 | 0.52 | Reliable |
| MCvD | 0.92 | 0.51 | Reliable |

It shows that the construct reliability is above 0.7. The variance extracted is above 0.5 for both MCvTA and MCvD instruments, indicating that the construct reliability and variance extracted from the MCvTA and MCvD instruments have met the minimum standards in measuring the research variables (Chan & Lay, 2018; Chuenban et al., 2021; Folse et al., 2010; Fornell & Larcker, 1981; Kornpitack & Sawmong, 2022; Smith et al., 2014; Theriou et al., 2011). In other words, the reliability of the MCvTA and MCvD measurement models is adequate, and students' responses to items in measuring MCvTA and MCvD are consistent.

The questions for the fluency dimension involve assessing the students' proficiency in providing examples of three pairs of sets and their capacity to determine the number of potential relationships that can be established between these two sets. In addition, the questions for this fluency dimension also concern students' ability to identify the relationship between cartesian multiplication and the relation of the two sets. Based on the mean of the fluency dimension, 50% of the ideal score has been reached. Based on the answers written on the answer sheet, students could provide examples of three pairs of sets and determine the number of possible relations that can be made between two sets. Nonetheless, students encounter challenges identifying the relationship between cartesian multiplication and the relation between the two sets established. Students also needed help in writing the argumentation of the answers they proposed. This observation suggests that students struggle to forge connections between distinct mathematical concepts or situations (Eli et al., 2013; Kenedi et al., 2019; Ormond, 2016). Writing arguments for answers is more complicated than getting the answer (Gürefe, 2018; Kaur & Prendergast, 2022).

Some students misunderstood the problem and thus provided inappropriate answers. For example, students gave answers in the form of three sets with the same number of members, such as A = {Risa, Futria, Trizkia}, B = {Red, Blue, Pink}, and C = {Meatball, Fried Rice, Noodle}. In contrast, the problem asks to provide examples of three pairs of sets with the same number of possible relations for each pair. So, based on students' answers to the fluency dimension problems, it shows that students in this research sample had yet to display many ideas or opinions optimally.

The problems for the flexibility dimension concern students' ability to propose ways to determine the number of mappings from one set to another set. In addition, this question is also related to students' ability to discover how to arrange these mappings expressed in arrow diagrams. Students with high flexibility will have more than one way of arranging. The results of the measurement of the flexibility dimension revealed that most students created one solution only, with almost similar methods. Another finding showed that some students provided incorrect answers because the arrow diagram made was not a mapping but only an ordinary relation or a relation arrow diagram. This finding was highlighted by the mean for flexibility problem (around 50%). Students could solve the problem but need help proposing many solutions (Achmetli et al., 2019; Schoevers et al., 2022), even though the problem requires multiple methods. Hence, an analysis of students' responses to the flexibility dimension problems indicates that participants within this research cohort need to exhibit an optimal capacity for manifesting diverse methods or approaches when solving mathematical problems.

The problems for the elaboration dimension relate to students' ability to compile function tables, sketch the graphs of linear functions and quadratic functions on the cartesian coordinate plane, and show the similarities and differences between the graphs of linear functions and quadratic functions. Students with high elaboration will compile function tables, draw function graphs, and identify differences and similarities between two function graphs in detail. The results for this elaboration dimension found that most students could compile the linear function table and quadratic function requested by the problems. However, some students only provided the linear function graph. In addition, the findings also showed that students did not get the ideal score because the function table they compiled was less precise. The inaccuracy arose from the presumption that the origin of the function graph should be constrained to integers, leading students to depict the graph in a dot-like manner. However, it should be noted that the problem explicitly specifies the domain and codomain as real numbers, resulting in a function graph taking the shape of a continuous curve.

The function tables and graphs generated by students needed more precision and detail. Consequently, the observations made by students regarding the similarities and differences between the two drawn function graphs needed to have been more thorough and yielded a substantial number of similarities and differences. Student achievement for this elaboration dimension was below 50% of the ideal score. Students perceive their written responses to be lucid and accurate, which may lead them to allocate lesser attention to elements that necessitate comprehensive elaboration within the overarching solution, essential for correcting their answers (Feudel & Unger, 2022; Gurat, 2018). Hence, based on students' responses to the elaboration dimension problems, it is said that this research cohort did not exhibit an optimal capacity for developing ideas, enhancing and evolving concepts, and establishing connections among facts and principles when addressing mathematical problems.

The originality dimension problems pertain to students' capacity to provide examples of real-life problems that can be addressed using the concepts of relation, function, or one-on-one correspondence. Based on the mean generated from the responses to these originality dimension problems, it is evident that students encounter challenges when presenting distinctive and novel real-life examples of problems to solve using the mentioned concepts. Most student responses predominantly featured common textbook problems or those provided by teachers during the lessons. Some students only limited their responses to constructing arrow diagrams without providing mathematical problems related to the arrow diagram model. The need for more demonstration of originality within student answers was reflected in the mean of originality problems, below 50% of the ideal score, constituting the lowest achievement score among other dimensions in the MCvTA. These findings suggest that devising original, unique, non-trivial, or infrequently proposed ideas, answers, or methods presents a formidable challenge for students in the MCvTA assessment. Indeed, originality is recognized as a particularly demanding dimension of creative thinking ability, surpassing the challenges posed by other dimensions (Rabi & Masran, 2016) and requiring a robust foundation of flexible reasoning (Grégoire, 2016). In summary, the student's responses to originality dimension problems indicate that participants did not attain optimal achievement, particularly concerning their capability to generate original, unique, non-trivial, or infrequently proposed ideas, answers, or methods in solving mathematical problems.

Overall, the attainment levels of each dimension on the MCvTA for functions were relatively similar. Each dimension of MCvTA yielded an approximate achievement level of 50% of the ideal score. The MCvTA encompassed algebra (relations and functions) and creative thinking skills in this study. The achievement being 50% of the ideal score mark could manifest in three scenarios: the material content achievement surpassing creative thinking ability content, material content achievement lagging behind creative thinking ability content, or a balance between material content and creative thinking ability content achievement. Notably, the mastery of the material and the proficiency in creative thinking skills, as demonstrated through solving MCvTA problems, remain interconnected. In other words, students might attain mastery in relations and functions yet need to exhibit stronger creative thinking skills, preventing them from showcasing the expected mastery of the material, as outlined by the criteria of creative thinking skill evaluation, and vice versa. So, creativity within the mathematical context, intrinsically linked to cognitive processes, assumes a performative character stemming from the fusion of mathematical material mastery and creative thinking skills (de Vink et al., 2022; Grégoire, 2016; Ibrahim & Widodo, 2020). Moreover, it is a common trend that the dimension of originality attains the lowest achievement, as evidenced across various studies (Ibrahim & Widodo, 2020; Rabi & Masran, 2016; Shaw et al., 2022).

The items for the risk-taking aspect pertain to the behavioral inclination to embrace the possibility of failure when engaging in mathematical learning, including formulating conjectures or estimates for solving mathematical problems and advocating for proposed ideas. The mean of the courage to take risks showed that students achieved over 50% of the ideal score (70%). These findings were based on students' responses to the items in the risk-taking courage aspect, underscoring that students possess a heightened preparedness to welcome criticism and diligently furnish arguments to uphold their concepts, even when subject to critique. However, this readiness to propose conjectures or estimates when addressing mathematical problems could be more pronounced. These findings indicate that students are willing to accept criticism and hypothesize or approximate solutions to provided problems while offering arguments for their ideas (Grégoire, 2016; Rabi & Masran, 2016). Hence, the students' responses to the risk-taking aspect in the MCvDS indicate that participants demonstrated a relatively strong disposition for risk-taking courage in learning mathematics.

The items for loving a challenging aspect correspond to the behavioral inclination of seeking multiple potential alternative solutions, sourcing materials for problem-solving, and actively embracing complex mathematics problems. The mean for this aspect was 61% of the ideal score. The finding revealed that students often tended to experience contentment when discovering a single idea or problem-solving approach, prompting them to cease exploring alternative ideas or solutions. However, students exhibited notable readiness when solving mathematical problems and diligently seeking ample reasoning for the problem-solving content. These findings showed that students tended to be ready to solve challenging mathematical problems and diligently seek comprehensive reasoning for their solutions; however, they tended to halt their search for additional ideas or alternative solutions once they had identified one potential solution (Schindler & Lilienthal, 2022). In summary, students' responses to the MCvDS items indicate that participants are inclined to embrace challenging problems, actively seek sufficient material for problem-solving, and demonstrate an intent to discover alternative solutions, even though these behavioral tendencies do not consistently rank within the higher range, particularly notable in discovering for alternative solutions.

The items for curiosity aspect correspond to the behavioral inclination of expressing a preference for posing queries about mathematical concepts that lack clarity, engaging with new ideas, exhibiting interest in contemplating abstract or concealed mathematical concepts, enjoying challenges presented by puzzles, and actively attempting to solve novel mathematical problems. The mean for this aspect reached 67% of the ideal score. This finding highlighted that students are inclined to inquire about unclear concepts, engage with activities stemming from novel mathematical concepts, display a curiosity for abstract mathematical ideas, enjoy puzzles, and demonstrate an eagerness to solve new mathematical challenges. However, the results also suggested that the propensity to ask questions about unclear concepts appears to be the least pronounced compared to other behaviors. This pattern could potentially be attributed to negative experiences or assumptions stemming from past encounters within the classroom environment, wherein students might feel embarrassed or hesitant to engage in asking questions (Bringula et al., 2021; Harunasari & Halim, 2019; Laine et al., 2020). Consequently, this might decrease students' likelihood of actively seeking clarification by posing questions in a classroom setting. Overall, the student's responses to the MCvDS indicate that the participants exhibited a relatively strong inclination toward curiosity in learning mathematics.

The items for imagination aspect reflect the behavioral inclination to visualize or depict the given situation or problem, generate alternate examples, and solve non-routine mathematical problems. The mean of this aspect was 66% of the ideal score. The students' responses underscored that students had a commendable inclination to conjure visualizations or illustrations for the situation or problem and to devise alternative examples different from the pre-existing ones. However, findings also indicate that the behavior of solving non-routine mathematical problems is the least pronounced among other behaviors. It can be interpreted that students tended to avoid non-routine mathematical problems requiring the formulation of solutions beyond the application of established formulas or entail answers that cannot be preemptively foreseen (Andrade et al., 2020; Doorman et al., 2007; Street et al., 2022). So, the findings indicate that participants exhibited a relatively robust imaginative disposition in mathematical learning. However, solving non-routine mathematical problems remains positioned in the medium category, suggesting room for further development.

Overall, the achievement scores across each aspect of the MCvD exhibit minimal variations. The measurement of each MCvD aspect fell within the interval of 60%-70% of the ideal score, which can be characterized as a moderate to high category. This finding suggests that students' behavioral inclinations towards creativity in mathematical learning are near the high category and display relatively consistent tendencies across the various aspects. Consequently, student creativity, inherently connected to these behavioral tendencies, maintains a consistent alignment throughout each aspect (Rabi & Masran, 2016).

The results of this study indicate a significant reciprocal or non-recursive causal relationship between MCvTA and MCvD. This finding signifies that students' MCvTA impacts their MCvD and vice versa. In other words, students' MCvTA can be elucidated through their MCvD, and conversely, students' MCvD can also be explained by their MCvTA.

The reciprocal cause-and-effect relationship between MCvTA and MCvD indicates their interconnectedness in mathematics learning, ultimately fostering creativity. Similar findings from previous studies also highlighted that cognitive and affective aspects interact during students' mathematical learning experiences (Aizikovitsh-Udi & Cheng, 2015; Álvarez-Huerta et al., 2022; Barnes, 2019, 2021; Di Martino & Zan, 2011; Fiori et al., 2022). Furthermore, students' mathematical reasoning in solving mathematical problems can be influenced by the emotions they experience (Hannula, 2012). This study found that when students engaged with algebraic problems requiring the dimensions of MCvTA (relations and functions), they concurrently needed support from MCvD aspects. For example, while addressing the originality dimension, which involves generating unique examples related to relations, functions, or one-on-one correspondence in daily life, students need the imagination aspect because they need to present distinct examples by employing their imagination. Conversely, students' imaginative prowess directly results from their ability to think creatively, producing original ideas. Therefore, MCvTA and MCvD are not one of contradiction or separation in the context of creativity; instead, they synergistically complement each other in cultivating mathematical creativity.

As an illustration of the MCvTAT context, students solved the following problem for the elaboration dimension on relations and functions.

a. Create *a* table for the functions: $x \rightarrow x^2$ and $x \rightarrow x + 1$ from the set Q = {-4, -3, -2, -1, 0, 1, 2, 3, 4} to the set of integers.
b. If the domain and codomain are sets of real numbers, sketch the graphs of the two functions in point *a* on the cartesian coordinate.
c. Show the similarities and differences you found between the two functions.

The given problems necessitate a grasp of fundamental concepts, including function definition, function formula, function values from domain elements, range determination, and the illustration of linear and quadratic function graphs. Most students addressed point b by plotting dots that represent pairs of x-values and corresponding function (y) values. The lack of students' curiosity seemingly influenced their incorrect responses, potentially stemming from a failure to thoroughly explore the problem details that specify the domain and codomain as sets of real numbers. When examining this situation through the lens of the elaboration dimension associated with the loving a challenge aspect, it is apparent that the extent of students' elaborative thinking can impact how they address items concerning the loving a challenge aspect. Specifically, it might influence students to discontinue searching for supplementary ideas to discover alternative solutions. Students' inclination to react unfavorably to statements regarding the loving a challenge aspect likely emerges from their infrequent engagement with intricate thinking in mathematical problem-solving. This implies that students may tend to operate under the assumption that their proposed solutions are accurate and comprehensive. This tendency highlights that students often need more time to halt the pursuit of ideas or detailed elaboration if they feel their provided response is accurate or thorough (Schindler & Lilienthal, 2022).

For example, in the MCvDS context, students responded to items for the imagination aspect as follows.

a. I find it challenging to illustrate ideas about a mathematical concept learned.
b. I need to think more actively of other examples to explain a mathematical concept.
c. I enjoy trying to solve non-routine math problems.

The students' elaboration dimension will influence their responses to the above items. This influence emanates from the behaviors embedded within the imagination aspect, encompassing the illustration of ideas, the generation of diverse examples, and the attempt to solve non-routine mathematical problems, which require students' abilities to elucidate and establish connections between the facts thoroughly (Kattou et al., 2013). Moreover, students' originality dimension also plays a role in shaping their responses to the items. This is underscored by the behaviors inherent in the imagination aspect, demanding students' capacity to provide distinctive and relevant ideas beyond the conventional scope (Karwowski et al., 2017).

The creative behavioral tendencies of students hold a reciprocal influence over their creative thinking, and conversely, students' creative thinking capabilities reciprocally shape their creative behavioral tendencies. Students' inclination towards risk-taking significantly contributes to their capacity to generate numerous and flexible ideas. This is facilitated by their willingness to risk potential idea rejection or inaccuracy. Furthermore, students' meticulous approach to solving mathematical problems requires the support of behavioral tendencies, such as exploring materials for problem-solving and proposing varied ideas for detailing problem-solving. Students' inherent tendency to imagine and embrace challenges similarly requires reinforcement through their proficiency in detailed thinking and originality. Consequently, the reciprocal causal relationship between the dimensions of MCvTA and the aspects of MCvD leads to mutual influence, mutual complementarity, enhanced strength, cohesiveness, and interactive dynamics that collectively contribute to the emergence of mathematical creativity. This finding resonates with existing research, highlighting that cognitive and affective aspects operate synergistically to foster creativity (Fiori et al., 2022; Sumarmo et al., 2012).

This structural relationship model between MCvTA and MCvD found in this study offers valuable insights for shaping mathematics instruction within classrooms oriented toward nurturing mathematical creativity. This study's findings reveal that the classroom's mathematical learning process should not singularly emphasize MCvTA development; rather, MCvD development should also be an integral focus. To effectively facilitate the simultaneous and balanced development of both MCvTA and MCvD, various aspects of the learning environment need careful consideration, including designing learning scenarios, teaching material presentations, mathematical activities, and assessment tools. Ensuring a harmonious equilibrium in cultivating MCvTA and MCvD during mathematics learning holds significant promise in engendering optimal mathematical creativity. This perspective aligns with the findings of similar studies, emphasizing the notion that comprehensive mathematics learning outcomes are most effectively achieved when both cognitive and affective dimensions are maximized (Aizikovitsh-Udi & Cheng, 2015; Álvarez-Huerta et al., 2022; Barnes, 2019, 2021; Bicer et al., 2020; Di Martino & Zan, 2011; Fiori et al., 2022).

## CONCLUSION

Existing research focuses on creative thinking abilities in mathematics learning, but this research does not link it to creative dispositions. This research found that mathematical creative thinking ability and mathematical creative disposition share a reciprocal cause-and-effect relationship. Students' creative thinking ability influences their creative disposition, and vice versa. Cognitive creativity embodies a performance that emanates from a fusion of mastery of mathematical concepts and creative thinking skills. Meanwhile, students' creativity concerning behavioral tendencies demonstrates alignment among various dimensions. This reciprocal cause-and-effect relationship between creative thinking ability and mathematical creative disposition underscores the imperative for mathematics education to emphasize the cultivation of both aspects concurrently and harmoniously. This approach is pivotal in achieving optimal levels of creativity in students' mathematical endeavors.

Furthermore, this study recommends the importance of paying attention to students' thinking skills in mathematics classes at different educational levels, posing mathematical problems that enhance mathematical creativity, and training teachers to provide teaching practices that develop mathematical creativity. Mathematics learning activities in class carried out by students should not only focus students on their creative thinking abilities, but creative dispositions also need to be the focus of these activities. Mathematical problems that teachers pose to students should not only make students work with pencil and paper but also make students carry out actions or behaviors that can trigger the development of creative dispositions.

This research has found several things that can be used theoretically and practically; however, this research has limitations. One of the limitations is that it is only limited to mathematical topics about relations and functions, so research on other mathematical topics is needed. Another limitation is that the population is small, so replication studies can be carried out for other populations with larger sizes. Despite the limitations of this research, however, these findings bear implications for developing instructional materials and mathematics education strategies, thus offering a foundation for future research endeavors. Finally, the research that can be carried out in the future is qualitative studies to discover mathematics teachers' beliefs regarding students' creativity abilities and their perceptions regarding their teaching competence to develop creativity. Studies can also be conducted to evaluate the performance of mathematics teachers in teaching practices related to creativity and pose problems that develop creativity and the strategies used for that. Other research that can be carried out based on the findings of this research is research into the development of learning models and learning tools, which focus on the balance between creative thinking abilities and creative dispositions to be improved.

## Acknowledgments

The researchers express their profound gratitude for the invaluable collaborative efforts that transpired among three eminent academic institutions during this study. Special acknowledgment is extended to Universitas Islam Negeri Sunan Kalijaga Yogyakarta, Indonesia, the University of Bisha, Saudi Arabia, and Universitas Ahmad Dahlan, Indonesia. These esteemed institutions generously contributed by furnishing indispensable resources, including conducive research environments, expert guidance, and state-of-the-art facilities, which were pivotal in facilitating the successful execution of this research endeavor. Lastly, special thanks to the Deanship of Scientific Research at University of Bisha for supporting this work through the Research Support Program.

## Declarations

| | | |
|---|---|---|
| Author Contribution | : | I: Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Editing, and Visualization.<br>IAK: Adding Clips and References, Review, Editing, Validation, and Supervision.<br>RCIP: Methodology, Formal Analysis, Review, Editing, Validation, and Supervision. |
| Funding Statement | : | This research was funded by the Department of Mathematics Education, Universitas Islam Negeri Sunan Kalijaga, Indonesia, and the Deanship of Scientific Research, University of Bisha, Saudi Arabia, through the Research Support Program. |
| Conflict of Interest | : | The authors declare no conflict of interest. |
| Additional Information | : | Additional information is available for this paper. |


## REFERENCES

21st Century Skills Map. (2012). *Creativity and innovation: math*. America Partnership for 21st Century Skills. https://files.eric.ed.gov/fulltext/ED543032.pdf

Achmetli, K., Schukajlow, S., & Rakoczy, K. (2019). Multiple solutions for real-world problems, experience of competence and students' procedural and conceptual knowledge. *International Journal of Science and Mathematics Education*, *17*(8), 1605–1625. https://doi.org/10.1007/s10763-018-9936-5

Aiken, L. R. (1980). Content validity and reliability of single items or questionnaires. *Educational and Psychological Measurement*, *40*(4), 955–959. https://doi.org/10.1177/001316448004000419

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131–142. https://doi.org/10.1177/0013164485451012

Aizikovitsh-Udi, E., & Amit, M. (2011). Developing the skills of critical and creative thinking by probability teaching. *Procedia - Social and Behavioral Sciences*, *15*, 1087–1091. https://doi.org/10.1016/j.sbspro.2011.03.243

Aizikovitsh-Udi, E., & Cheng, D. (2015). Developing critical thinking skills from dispositions to abilities: mathematics education from early childhood to high school. *Creative Education*, *6*(4), 455–462. https://doi.org/10.4236/ce.2015.64045

Álvarez-Huerta, P., Muela, A., & Larrea, I. (2022). Disposition toward critical thinking and creative confidence beliefs in higher education students: the mediating role of openness to diversity and challenge. *Thinking Skills and Creativity*, *43*(12), 1–9. https://doi.org/10.1016/j.tsc.2022.101003

Andrade, R. R., Fortes, E. C., & Mabilangan, R. A. (2020). Problem solving heuristics and mathematical abilities of heterogeneous learners. *Universal Journal of Educational Research*, *8*(11), 5114–5126. https://doi.org/10.13189/ujer.2020.081111

Bagozzi, R. P. (1977). Structural equation models in experimental research. *Journal of Marketing Research*, *14*(2), 209–226. https://doi.org/10.2307/3150471

Bagozzi, R. P. (1980). Performance and satisfaction in an industrial sales force: an examination of their antecedents and simultaneity. *Journal of Marketing*, *44*(2), 65–77. https://doi.org/10.1177/002224298004400208

Bardini, C., Pierce, R., Vincent, J., & King, D. (2014). Undergraduate mathematics students' understanding of the concept of function. *Journal on Mathematics Education*, *5*(2), 85–107. https://doi.org/10.22342/jme.5.2.1495.85-107

Barnes, A. (2019). Perseverance in mathematical reasoning: the role of children's conative focus in the productive interplay between cognition and affect. *Research in Mathematics Education*, *21*(3), 271–294. https://doi.org/10.1080/14794802.2019.1590229

Barnes, A. (2021). Enjoyment in learning mathematics: its role as a potential barrier to children's perseverance in mathematical reasoning. *Educational Studies in Mathematics*, *106*(1), 45–63. https://doi.org/10.1007/s10649-020-09992-x

Bevan, D., & Capraro, M. M. (2021). Posing creative problems: a study of elementary students' mathematics understanding. *International Electronic Journal of Mathematics Education*, *16*(3), em0654. https://doi.org/10.29333/iejme/11109

Bicer, A., Lee, Y., Perihan, C., Capraro, M. M., & Capraro, R. M. (2020). Considering mathematical creative self-efficacy with problem posing as a measure of mathematical creativity. *Educational Studies in Mathematics*, *105*(3), 457–485. https://doi.org/10.1007/s10649-020-09995-8

Bringula, R., Reguyal, J. J., Tan, D. D., & Ulfa, S. (2021). Mathematics self-concept and challenges of learners in an online learning environment during COVID-19 pandemic. *Smart Learning Environments*, *8*(22), 1–23. https://doi.org/10.1186/s40561-021-00168-5

Bulut, D., Samur, Y., & Cömert, Z. (2022). The effect of educational game design process on students' creativity. *Smart Learning Environments*, *9*(8), 1–18. https://doi.org/10.1186/s40561-022-00188-9

Cangur, S., & Ercan, I. (2015). Comparison of model fit indices used in structural equation modeling under multivariate normality. *Journal of Modern Applied Statistical Methods*, *14*(1), 152–167. https://doi.org/10.22237/jmasm/1430453580

Chan, S. H., & Lay, Y. F. (2018). Examining the reliability and validity of research instruments using partial least squares structural equation modeling (PLS-SEM). *Journal of Baltic Science Education*, *17*(2), 239–251. https://doi.org/10.33225/jbse/18.17.239

Chermahini, S. A., & Hommel, B. (2012). Creative mood swings: divergent and convergent thinking affect mood in opposite ways. *Psychological Research*, *76*(5), 634–640. https://doi.org/10.1007/s00426-011-0358-z

Chicco, D., Warrens, M. J., & Jurman, G. (2021). The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. *PeerJ Computer Science*, *7*(e623), 1–24. https://doi.org/10.7717/PEERJ-CS.623

Chong, M. S. F., Shahrill, M., & Li, H. C. (2019). The integration of a problem-solving framework for Brunei high school mathematics curriculum in increasing student's affective competency. *Journal on Mathematics Education*, *10*(2), 215–228. https://doi.org/10.22342/jme.10.2.7265.215-228

Chuenban, P., Sornsaruht, P., & Pimdee, P. (2021). How brand attitude, brand quality, and brand value affect Thai canned tuna consumer brand loyalty. *Heliyon*, *7*(2), e06301. https://doi.org/10.1016/j.heliyon.2021.e06301

Conner, A. M., Singletary, L. M., Smith, R. C., Wagner, P. A., & Francisco, R. T. (2014). Teacher support for collective argumentation: A framework for examining how teachers support students' engagement in mathematical activities. *Educational Studies in Mathematics*, *86*, 401–429. https://doi.org/10.1007/s10649-014-9532-8

Creswell, J. W. (2012). *Educational research: planning, conducting and evaluating quantitative and qualitative research*. Pearson.

Creswell, J. W., & Creswell, D. W. (2018). *Research design qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

Daher, W., Gierdien, F., & Anabousy, A. (2021). Self-efficacy in creativity and curiosity as predicting creative emotions. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *6*(2), 86–99. https://doi.org/10.23917/jramathedu.v6i2.12667

de Vink, I. C., Willemsen, R. H., Lazonder, A. W., & Kroesbergen, E. H. (2022). Creativity in mathematics performance: the role of divergent and convergent thinking. *British Journal of Educational Psychology*, *92*(2), 484–501. https://doi.org/10.1111/bjep.12459

Di Martino, P., & Zan, R. (2011). Attitude towards mathematics: A bridge between beliefs and emotions. *ZDM - International Journal on Mathematics Education*, *43*(4), 471–482. https://doi.org/10.1007/s11858-011-0309-6

Doorman, M., Drijvers, P., Dekker, T., van den Heuvel-Panhuizen, M., de Lange, J., & Wijers, M. (2007). Problem solving as a challenge for mathematics education in The Netherlands. *ZDM*, *39*(5), 405–418. https://doi.org/10.1007/s11858-007-0043-2

Edwards, A. L. (1957). The method of successive intervals. In A. L. Edwards (Ed.), *Techniques of attitude scale construction* (pp. 120–148). Appleton-Century-Crofts. https://doi.org/10.1037/14423-005

Elgrably, H., & Leikin, R. (2021). Creativity as a function of problem-solving expertise: posing new problems through investigations. *ZDM - Mathematics Education*, *53*(4), 891–904. https://doi.org/10.1007/s11858-021-01228-3

Eli, J. A., Mohr-Schroeder, M. J., & Lee, C. W. (2013). Mathematical connections and their relationship to mathematics knowledge for teaching geometry. *School Science and Mathematics*, *113*(3), 120–134. https://doi.org/10.1111/ssm.12009

Ennis, R. H. (1993). Critical thinking assessment. *Theory Into Practice*, *32*(3), 179–186. https://doi.org/10.1017/CBO9781107415324.004

Felson, R. B., & Bohrnstedt, G. W. (1979). "Are the good beautiful or the beautiful good?" the relationship between children's perceptions of ability and perceptions of physical attractiveness. *Social Psychology Quarterly*, *42*(4), 386–392. https://doi.org/10.2307/3033808

Feudel, F., & Unger, A. (2022). Students ' strategic usage of formative quizzes in an undergraduate course in abstract algebra. *International Journal of Research in Undergraduate Mathematics Education*. https://doi.org/10.1007/s40753-022-00194-9

Fikriyatii, A., Surabaya, U. N., Agustini, R., Surabaya, U. N., Sutoyo, S., Surabaya, U. N., Planning, H. E., & Board, C. (2022). Critical thinking cycle model to promote critical thinking disposition and critical thinking skills of pre-service science teacher. *Cypriot Journal of Educational Sciences*, *17*(1), 120–133. https://doi.org/10.18844/cjes.v17i1.6690

Fiori, M., Fischer, S., & Barabasch, A. (2022). Creativity is associated with higher well-being and more positive COVID-19 experience. *Personality and Individual Differences*, *194*(3), 111646. https://doi.org/10.1016/j.paid.2022.111646

Folse, J. A. G., Niedrich, R. W., & Grau, S. L. (2010). Cause-relating marketing: The effects of purchase quantity and firm donation amount on consumer inferences and participation intentions. *Journal of Retailing*, *86*(4), 295–309. https://doi.org/10.1016/j.jretai.2010.02.005

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(3), 382–388. https://doi.org/10.2307/3151312

Garcia, J. G., & Mukhopadhyay, T. P. (2019). The role and efficacy of creative imagination in concept formation: A study of variables for children in primary school. *Education Sciences*, *9*(3), 175. https://doi.org/10.3390/educsci9030175

Gay, L. R., Mills, G. E., & Airasian, P. (2012). *Educational research: competencies for analysis and applications*. Pearson Education, Inc.

Grégoire, J. (2016). Understanding creativity in mathematics for improving mathematical education. *Journal of Cognitive Education and Psychology*, *15*(1), 24–36. https://doi.org/10.1891/1945-8959.15.1.24

Guadagnoli, E., & Velicer, W. F. (1988). Relation of sample size to the stability of component patterns. *Psychological Bulletin*, *103*(2), 265–275. https://doi.org/10.1037/0033-2909.103.2.265

Gurat, M. G. (2018). Mathematical problem-solving strategies among student teachers. *Journal on Efficiency and Responsibility in Education and Science*, *11*(3), 53–64. https://doi.org/10.7160/eriesj.2018.110302

Gürefe, N. (2018). Mathematical language skills of mathematics prospective teachers. *Universal Journal of Educational Research*, *6*(4), 661–671. https://doi.org/10.13189/ujer.2018.060410

Hannula, M. S. (2012). Exploring new dimensions of mathematics-related affect: embodied and social theories. *Research in Mathematics Education*, *14*(2), 137–161. https://doi.org/10.1080/14794802.2012.694281

Harunasari, S. Y., & Halim, N. (2019). Digital backchannel: Promoting students' engagement in EFL large class. *International Journal of Emerging Technologies in Learning*, *14*(7), 163–178. https://doi.org/10.3991/ijet.v14i07.9128

Herwin, & Nurhayati, R. (2021). Measuring students' curiosity character using confirmatory factor analysis. *European Journal of Educational Research*, *10*(2), 773–783. https://doi.org/10.12973/EU-JER.10.2.773

Hsu, S. H., Chen, W. H., & Hsieh, M. J. (2006). Robustness testing of PLS, LISREL, EQS and ANN-based SEM for measuring customer satisfaction. *Total Quality Management and Business Excellence*, *17*(3), 355–372. https://doi.org/10.1080/14783360500451465

Ibrahim, I., Sujadi, I., Maarif, S., & Widodo, S. A. (2021). Increasing mathematical critical thinking skills using advocacy learning with mathematical problem solving. *Jurnal Didaktik Matematika*, *8*(1), 1–14. https://doi.org/10.24815/jdm.v8i1.19200

Ibrahim, I., & Widodo, S. A. (2020). Advocacy approach with open-ended problems to mathematical creative thinking ability. *Infinity Journal*, *9*(1), 93. https://doi.org/10.22460/infinity.v9i1.p93-102

Isyrofinnisak, F., Kusmayadi, T. A., & Fitriana, L. (2020). Mathematics creativity skill of student in junior high school based on students thinking style. *Journal of Physics: Conference Series*, *1538*(1). https://doi.org/10.1088/1742-6596/1538/1/012068

Jagals, D., & van der Walt, M. (2019). Metacognitive awareness and visualisation in the imagination: the case of the invisible circles. *Pythagoras*, *40*(1), a464. https://doi.org/10.4102/pythagoras.v40i1.464

Jonsson, B., Granberg, C., & Lithner, J. (2020). Gaining mathematical understanding: The effects of creative mathematical reasoning and cognitive proficiency. *Frontiers in Psychology*, *11*(December), 1–16. https://doi.org/10.3389/fpsyg.2020.574366

Jonsson, B., Mossegård, J., Lithner, J., & Karlsson Wirebring, L. (2022). Creative mathematical reasoning: does need for cognition matter? *Frontiers in Psychology*, *12*(January), 1–10. https://doi.org/10.3389/fpsyg.2021.797807

Jöreskog, K. G., & Sörbom, D. (1993). LISREL 8: Structural equation modeling with the SIMPLIS command language. In *Scientific Software International*.

Kadir, K., Lucyana, L., & Satriawati, G. (2016). The implementation of open-inquiry approach to improve students' learning activities, responses, and mathematical creative thinking skills. *Journal on Mathematics Education*, *8*(1), 103–114. https://doi.org/10.22342/jme.8.1.3406.103-114

Kalelioğlu, F., & Gülbahar, Y. (2014). International forum of educational technology & society the effect of instructional techniques on critical thinking and critical thinking dispositions in online discussion. *Educational Technology & Society*, *17*(1), 248–258. http://www.jstor.org/stable/jeductechsoci.17.1.248

Kanoknitanunt, P., Nilsook, P., & Wannapiroon, P. (2021). Imagineering learning with logical problem solving. *Journal of Education and Learning*, *10*(3), 112–121. https://doi.org/10.5539/jel.v10n3p112

Karwowski, M., Jankowska, D. M., & Szwajkowski, W. (2017). Creativity, imagination, and early mathematics education. In B. Leikin, R., Sriraman (Ed.), *Creativity and Giftedness. Advances in Mathematics Education* (pp. 7–22). Springer, Cham. https://doi.org/10.1007/978-3-319-38840-3_2

Kashdan, T. B., Stiksma, M. C., Disabato, D. D., McKnight, P. E., Bekier, J., Kaji, J., & Lazarus, R. (2018). The five-dimensional curiosity scale: capturing the bandwidth of curiosity and identifying four unique subgroups of curious people. *Journal of Research in Personality*, *73*, 130–149. https://doi.org/10.1016/j.jrp.2017.11.011

Kattou, M., Kontoyianni, K., Pitta-Pantazi, D., & Christou, C. (2013). Connecting mathematical creativity to mathematical ability. *ZDM - International Journal on Mathematics Education*, *45*(2), 167–181.

https://doi.org/10.1007/s11858-012-0467-1

Kaur, T., & Prendergast, M. (2022). Students' perceptions of mathematics writing and its impact on their enjoyment and self-confidence. *Teaching Mathematics and Its Applications: An International Journal Ofthe IMA*, *41*(1), 1–21. https://doi.org/10.1093/teamat/hrab008

Kenedi, A. K., Helsa, Y., Ariani, Y., Zainil, M., & Hendri, S. (2019). Mathematical connection of elementary school students to solve mathematical problems. *Journal on Mathematics Education*, *10*(1), 69–80. https://doi.org/10.22342/jme.10.1.5416.69-80

Kerlinger, F. N. (1967). The first- and second-order factor structures of attitudes toward. *American Educational Research Journal*, *4*(3), 191–205. https://doi.org/10.2307/1161610

Khalil, I., & Alnatheer, M. (2020). Developing a learning unit in light of the integration between the mathematical proficiency and the 21st century skills. *INTED2020 Proceedings*, *1*(April), 2501–2506. https://doi.org/10.21125/inted.2020.0761

Kornpitack, P., & Sawmong, S. (2022). Empirical analysis of factors influencing student satisfaction with online learning systems during the COVID-19 pandemic in Thailand. *Heliyon*, *8*(3), e09183. https://doi.org/10.1016/j.heliyon.2022.e09183

Kurniati, Kusumah, Y. S., Sabandar, J., & Herman, T. (2015). Mathematical critical thinking ability. *Journal on Mathematics Education*, *6*(1), 53–62. https://doi.org/10.22342/jme.6.1.1901.53-62

Laine, A., Ahtee, M., & Näveri, L. (2020). Impact of teacher's actions on emotional atmosphere in mathematics lessons in primary school. *International Journal of Science and Mathematics Education*, *18*(1), 163–181. https://doi.org/10.1007/s10763-018-09948-x

Lubart, T. I., Zenasni, F., & Barbot, B. (2013). Creative potential and its measurement. *International Journal for Talent Development and Creativity*, *1*(2), 41–51. http://www.ijtdc.net/images/pdf/IJTDC_12_2013_Web.pdf

Niu, W., Cheng, L., Duan, D., & Zhang, Q. (2022). Impact of perceived supportive learning environment on mathematical achievement: the mediating roles of autonomous self-regulation and creative thinking. *Frontiers in Psychology*, *12*(781594), 1–9. https://doi.org/10.3389/fpsyg.2021.781594

Oliveira, H., Polo-Blanco, I., & Henriques, A. (2021). Exploring prospective elementary mathematics teachers' knowledge: a focus on functional thinking. *Journal on Mathematics Education*, *12*(2), 257–278. https://doi.org/10.22342/jme.12.2.13745.257-278

Ormond, C. (2016). Scaffolding the mathematical "connections": a new approach to preparing teachers for the teaching of lower secondary algebra. *Australian Journal of Teacher Education*, *41*(6), 122–164. https://doi.org/10.14221/ajte.2016v41n6.8

Ovando-Tellez, M., Benedek, M., Kenett, Y. N., Hills, T., Bouanane, S., Bernard, M., Belo, J., Bieth, T., & Volle, E. (2022). An investigation of the cognitive and neural correlates of semantic memory search related to creative ability. *Communications Biology*, *5*(604), 1–16. https://doi.org/10.1038/s42003-022-03547-x

Ozer, D. J. (1985). Correlation and the coefficient of determination. *Psychological Bulletin*, *97*(2), 307–315. https://doi.org/10.1037/0033-2909.97.2.307

Ozkal, N. (2019). Relationships between self-efficacy beliefs, engagement and academic performance in math lessons. *Cypriot Journal of Education*, *14*(2), 190–200. https://doi.org/10.18844/cjes.v14i2.3766

Powell, S. R., Fuchs, L. S., & Fuchs, D. (2013). Reaching the mountaintop: addressing the common core standards in mathematics for students with mathematics difficulties. *Learning Disabilities Research and Practice*, *28*(1), 38–48. https://doi.org/10.1111/ldrp.12001

Rabi, N. M., & Masran, M. N. Bin. (2016). Creativity characteristics in teaching students with learning disabilities among pre-service teacher in UPSI. *International Journal of Advanced and Applied Sciences*, *3*(11), 66–72. https://doi.org/10.21833/ijaas.2016.11.012

Rahmawati, L., & Ibrahim, I. (2021). Mathematical logical intelligence and linguistics as predictor of students mathematics learning outcomes. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(2), 245–256. https://doi.org/10.31980/mosharafa.v10i2.906

Ramdani, D., Susilo, H., Suhadi, & Sueb. (2022). The effectiveness of collaborative learning on critical thinking, creative thinking, and metacognitive skill ability: meta-analysis on biological learning. *European Journal of Educational Research*, *11*(3), 1607–1628. https://doi.org/10.12973/eu-jer.11.3.1607

Saraswati, S., Putri, R. I. I., & Somakim. (2016). Supporting students' understanding of linear equations with one variable using algebra tiles. *Journal on Mathematics Education*, *7*(1), 19–30. https://doi.org/10.22342/jme.7.1.2814.19-30

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, *8*(2), 23–74.

Schindler, M., & Lilienthal, A. J. (2022). Students' collaborative creative process and its phases in mathematics: an explorative study using dual eye tracking and stimulated recall interviews. *ZDM - Mathematics Education*, *54*(1), 163–178. https://doi.org/10.1007/s11858-022-01327-9

Schoevers, E. M., Kroesbergen, E. H., Moerbeek, M., & Leseman, P. P. M. (2022). The relation between creativity and students' performance on different types of geometrical problems in elementary education. *ZDM - Mathematics Education*, *54*(1), 133–147. https://doi.org/10.1007/s11858-021-01315-5

Setiyani, Putri, D. P., Ferdianto, F., & Fauji, S. H. (2020). Designing a digital teaching module based on mathematical communication in relation and function. *Journal on Mathematics Education*, *11*(2), 223–236. https://doi.org/10.22342/jme.11.2.7320.223-236

Setiyani, Waluya, S. B., Sukestiyarno, Y. L., & Cahyono, A. N. (2022). E-module design using kvisoft flipbook application based on mathematics creative thinking ability for junior high schools. *International Journal of Interactive Mobile Technologies*, *16*(4), 116–136. https://doi.org/10.3991/ijim.v16i04.25329

Shaw, S. T., Luna, M. L., Rodriguez, B., Yeh, J., Villalta, N., & Ramirez, G. (2022). Mathematical creativity in elementary school children: general patterns and effects of an incubation break. *Frontiers in Education*, *7*(835911), 1–8. https://doi.org/10.3389/feduc.2022.835911

Sinniah, C., Abdullah, A. H., & Osman, S. (2022). Preliminary study to enhance mathematical creativity in non-routine mathematics problem solving among primary school students. *Journal of Positive School …*, *6*(6), 3676–3686. https://www.journalppw.com/index.php/jpsp/article/view/7955

Smith, J. S., Gleim, M. R., Robinson, S. G., Kettinger, W. J., & Park, S. H. S. (2014). Using an old dog for new tricks: a regulatory focus perspective on consumer acceptance of RFID applications. *Journal of Service Research*, *17*(1), 85–101. https://doi.org/10.1177/1094670513501394

Street, K. E. S., Malmberg, L. E., & Stylianides, G. J. (2022). Changes in students' self-efficacy when learning a new topic in mathematics: a micro-longitudinal study. *Educational Studies in Mathematics*, *111*(3), 515–541. https://doi.org/10.1007/s10649-022-10165-1

Suhirman, S., Prayogi, S., & Asy'ari, M. (2021). Problem-based learning with character-emphasis and naturalist intelligence: examining students critical thinking and curiosity. *International Journal of Instruction*, *14*(2), 217–232. https://doi.org/10.29333/iji.2021.14213a

Sumarmo, U., Hidayat, W., Zukarnaen, R., Hamidah, & Sariningsih, R. (2012). Mathematical logical, critical, and creative abilities and dispositions (experiments on high school students using problem-based learning and think-talk-write strategies). *Journal of Teaching Mathematics and Natural Sciences*, *17*(1), 17–33. https://vm36.upi.edu/index.php/jpmipa/article/view/36048/15430

Tan, C. Y., Chuah, C. Q., Lee, S. T., & Tan, C. S. (2021). Being creative makes you happier: the positive effect of creativity on subjective well-being. *International Journal of Environmental Research and Public Health*, *18*(7244), 1–14. https://doi.org/10.3390/ijerph18147244

Tang, Y., & Hew, K. F. (2022). Effects of using mobile instant messaging on student behavioral, emotional, and cognitive engagement: a quasi-experimental study. *International Journal of Educational Technology in Higher Education*, *19*(3), 1–22. https://doi.org/10.1186/s41239-021-00306-6

Theriou, N., Maditinos, D., & Theriou, G. (2011). Knowledge management enabler factors and firm performance: an empirical research of the greek medium and large firms. *European Research Studies Journal*, *14*(2), 97–134. https://doi.org/10.35808/ersj/321

Toheri, Winarso, W., & Haqq, A. A. (2020). Where exactly for enhance critical and creative thinking: the use of problem posing or contextual learning. *European Journal of Educational Research*, *9*(2), 877–887. https://doi.org/10.12973/eu-jer.9.2.877

Turan, M. B., & Dişçeken, O. (2019). The effects of cognitive learning and imagination training on the balances of the 14-16 years old handball players. *Journal of Education and Training Studies*, *7*(1), 10–16. https://doi.org/10.11114/jets.v7i1.3834

Türkmen, H. (2015). Creative thinking skills analyzes of vocational high school. *Journal of Educational and Instructional Studies*, *5*(1), 74–84.

Utemov, V. V., & Masalimova, A. R. (2017). Differentiation of creative mathematical problems for primary school students. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(8), 4351–4362. https://doi.org/10.12973/eurasia.2017.00931a

Utemov, V. V., Ribakova, L. A., Kalugina, O. A., Slepneva, E. V., Zakharova, V. L., Belyalova, A. M., & Platonova, R. I. (2020). Solving math problems through the principles of scientific creativity. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(10), 1–9. https://doi.org/10.29333/EJMSTE/8478

Vacca, G., & Zoia, M. G. (2019). Identifying and testing recursive vs. interdependent links in simultaneous equation models via the SIRE package. *The R Journal*, *11*(1), 1–20. https://doi.org/10.32614/rj-2019-016

Vu, Q. C., Pham, D. T. T., & Le, D. C. (2022). Correlations among perception, emotion and behavior in sustainable development of mathematical creativity competency of primary school students in Vietnam. *Journal of Educational and Social Research*, *12*(1), 282–296. https://doi.org/10.36941/jesr-2022-0023

Wijayanto, H. S. (2015). *The research method uses structural equation modeling with LISREL 9*. FE UI.

Wright, S. (1921). Correlation and causation. *Journal of Agricultural Research*, *20*(7), 557–585. https://doi.org/10.1016/S0161-6420(13)30987-7

Wu, C. H., Liu, C. H., & Huang, Y. M. (2022). The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load. *International Journal of STEM Education*, *9*(35), 1–22. https://doi.org/10.1186/s40594-022-00346-y

Ximénez, C. (2009). Recovery of weak factor loadings in confirmatory factor analysis under conditions of model misspecification. *Behavior Research Methods*, *41*(4), 1038–1052. https://doi.org/10.3758/BRM.41.4.1038

Young, D. J. (1998). Ambition, self-concept , and achievement: a structural equation model for comparing rural and urban students. *Journal of Research in Rural Education*, *14*(1), 34–44.

Yu, M., & Chen, Z. (2021). The effect of aviation responses to the control of imported COVID-19 cases. *Journal of Air Transport Management*, *97*(102140), 1–15. https://doi.org/10.1016/j.jairtraman.2021.102140

Zhang, D. (2016). A coefficient of determination for generalized linear models. *The American Statistician*, *71*(4), 310–316. https://doi.org/10.1080/00031305.2016.1256839