

# Assessing Students' Mathematics Achievement and Mathematical Creativity using Mathematical Creative Approach: A Quasi-Experimental Research

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<https://doi.org/10.24191/ajue.v17i2.13399>

*Received:* 16 March 2021

*Accepted:* 3 May 2021

*Date Published Online:* 6 June 2021

*Published:* 6 June 2021

**Abstract:** There is an abundance of literature highlighting the need to focus on enhancing students' creativity in the classroom. This research aimed to determine the impact of the Mathematical Creative Approach (MCA) on mathematical creativity and mathematics achievement among students and to explore the relationship between mathematical creativity and achievement in mathematics. A quasi-experimental research design was employed for the study that included a total of 64 Form Four students from schools in Kuala Lumpur; 32 students in the intervention group and 32 students in the comparison group. The findings showed that those participants who were exposed to MCA reported significant positive changes in both outcome variables (mathematical creativity and mathematics achievement) as compared with those from the control group. Based on the results, there was also a high correlation between mathematical creativity and mathematics achievement. The research revealed that MCA has enormous capabilities to promote creativity; hence it should be integrated into pedagogical approaches to foster higher-quality learning among students. Additionally, the research results may serve as a guide for educators in Higher Learning institutions to design innovative curriculum for pre-service mathematics teachers, especially those being trained to integrate creativity and character development into student learning.

**Keywords:** Mathematical creative approach, Mathematical creativity, Mathematics achievement

## 1. Introduction

The Malaysia Education Blueprint 2013-2025 has outlined a major transformation plan to deliver higher quality education to students (MOE, 2015). A highly effective education system has to be visualised, and each student's aspirations are expressed according to the National Education Philosophy (MOE, 2015). It is also indicated that the thinking skills of students are the second aspiration, whereby cognitive skills, including the creativity element, should be encouraged among students. Therefore, creativity advancement among students is one of the most important elements in global education, including in Malaysia. In the case of mathematics, one technique to improve mathematical creativity among students is inspiring them to see mathematical problems as a challenge and to think differently. This approach will also enhance their enthusiasm for the subject.

One of the critical competencies in 21st-century learning involves creativity, and it is an essential skill in mathematics education (Kaplan, 2019; Richardson & Mishra, 2018; Silvia et al., 2013). However while creativity is acknowledged as a significant element in learning, it is also important for

the cognitive capabilities of a person to solve problems through the creation of new ideas as it is directly linked to the enhancement of ability and knowledge (Ghazali et al., 2020). However, the literature has highlighted the challenge of enhancing the creativity of secondary school students, especially in mathematics learning (Lee & Bailey, 2020). These range from rigid education management practices that aimed to increase creativity to the design of evaluation strategies that can easily assess creativity. However, there has been a great deal of debate about creativity and innovation in International mathematical societies.

Mathematical creativity, in particular, is often regarded as an essential component in research studies (Barraza-García et al., 2020; Isnani et al., 2020; Pitta-Pantazi et al., 2013). Mathematical creative learning is expected to provide students with the sort of learning that makes them more active and creative in resolving their problems. Students can learn this directly to resolve problems they encounter (Muda & Fook, 2020). However, students nowadays tend to use the recipe and memorise methods in solving mathematical problems without knowing the basic concepts (Tubb et al., 2020; Aizikovitsh-Udi, 2014; Roslan et al., 2021). The expectation is for students to solve mathematics problems more effectively and creatively. Every student can be creative when placed in a convenient setting (Kozlowski et al., 2019; Sternberg, 2006). To improve students' cognitive thinking, educators should cultivate mathematical creativity in all students. Improving mathematical creativity paves the way for inspiration, encouragement, and strong motivation for all students. Mathematics educators share the stance that creativity in mathematics can be enhanced if students are encouraged to think in different ways using a creative learning approach.

There is a significant amount of research on mathematical creativity that can benefit students (Cilli-Turner et al., 2021; Haavold, 2021; Maulidia et al., 2019). Nonetheless, these studies are focused on establishing the importance of mathematical creativity approaches and students' mathematics achievements in different environments, like in Hosseini and Watt (2010). There is limited research that relates these two variables—mathematical creativity and mathematics achievement—in a learning environment, especially in Malaysia. Besides, the studies were also focused on establishing the effects of creative mathematical approaches on mathematics achievements and general mathematical creativities among students. Little has been discussed about the distinction of mathematical creativity, namely fluency, flexibility, uniqueness, and elaboration, among secondary school students.

Despite the fact that Weinhandl and Lavicza (2021) claimed that mathematic creativity has been recognized as a reassurance of the field's growth. Mathematical innovative practices in mathematics classrooms, according to Isnani et al., (2020), have a significant effect on learners' mathematics achievement. Additionally, it could be narrowed down to a creative mathematical construct based on the distinction of mathematical creativity (fluency, flexibility, originality, and elaboration) like in the research by Fetterly (2010). Furthermore, based on the limitations of this study's findings regarding the relationship between mathematical achievement and mathematical creativity, there is a need for more research in this field. The primary goal of this research is to evaluate the use of the Mathematical Creative Approach (MCA) in secondary schools in Malaysia in terms of students' mathematical creativity and mathematics achievements.

## **2. Mathematical Creative Approach vs Conventional Learning Approach**

The use of MCA in a mathematics classroom is useful in improving the production of the four categories of mathematical creativity among learners, namely fluency, flexibility, uniqueness, and elaboration, in the intervention group (Khalid et al., 2020). For this study, the contents of the lesson were structured to be consistent with the syllabus of Form Four mathematics and chosen from the specific materials that were directly linked to it. Varieties of innovative approaches to learning are also included. It incorporates chapters on Quadratic Expressions and Quadratic Equations, Sets, Mathematical Reasoning, and The Straight Lines, all taught over six weeks. The questions posed by formal learning highlight the four mathematical creativity components in a mathematical context. Students were often required to solve problems that are linked to real-world scenarios and use mathematics to enhance their cognitive skills (Huang et al., 2017). Students were also guided in gathering ideas to do problem-solving. The approach also required students to share their solutions and to justify their ways of reflecting mathematical ideas.

The Conventional Learning Approach (CLA) was used on the control group for this study. CLA focuses on “chalk and talk” teaching and work drilling, a method that has long been used in mathematics classrooms. The core aspects of the control group's learning approaches are (i) the textbook and (ii) standard teaching methods. The students learn mathematical principles by recitation and formula memorisation. They were also divided into small groups to discuss learning content from the lessons given.

### 3. Method

#### 3.1 Research Design

To achieve the objectives of this research, a non-equivalent pre-test and post-test quasi-experimental design were used (Creswell, 2008; Graziano and Raulin, 2010; Cohen et al., 2000) as shown in Table 1:

**Table 1.** Research design.

Group	Pre-Application	During Application	Post-Process
Intervention group	O <sub>1</sub>	X <sub>1</sub>	O <sub>2</sub>
Control group	O <sub>1</sub>	X <sub>2</sub>	O <sub>2</sub>

Note: X<sub>1</sub> : Learning using MCA; X<sub>2</sub> : Learning using CLA; O<sub>1</sub> : Pre-test on mathematical creativity and mathematics achievement; O<sub>2</sub> : Post-test on mathematical creativity and mathematics achievement

The study took place in two typical class environments in two secondary schools, where one class comprises participating students from the intervention group and the other from the control group. The independent variable is the two separate approaches: MCA and CLA, while the dependent variable is the differences between the mean score of the pre-test and post-test for students' mathematics achievement and mathematical creativity from both groups.

#### 3.2 Population and Sample

The target population in this study was Form Four mathematics students in Form Four aged 16 years from secondary schools within Kuala Lumpur. This population is appropriate for this study as they were the groups whom participated in the Trends in International Mathematics and Science Study (TIMSS) and Programme for International Students Assessment (PISA). The study delimits to a specific geographic location and an exact time period. Thus, only Form Four students enrolled in two different secondary schools in Kuala Lumpur were selected as the sample groups. Two schools; one intervention group and one control group were sampled with an average of 32 students per school. This study was carried out in a normal secondary school class setting. The demographic variables between them were the same, so this made sure that the students' academic abilities are equivalent. Two schools were chosen using a purposeful sampling method, and the students were chosen using a simple random sampling technique.

The internal validity threats in research include instrumentation, testing, mortality, subject characteristics, implementation, testing, history, maturation, and implementation (Fraenkel, Wallen & Hyun, 2011). In this study, the researcher closely monitored the potential contamination of the results posed by these threats. For instance, in terms of characteristics, every attempt was made to ensure that the students are as homogeneous as possible concerning age, gender, and competency in mathematics. External validity is widely used to refer to the causal connection that could affect the variation in individuals, treatment, settings, treatments, and results (Leviton, 2015). In this study, the subject and setting background factors were held constant.

A pilot test was conducted for this research study to ensure the validity and reliability of the instruments were at acceptable levels. The instruments were given to a different group of 31 mathematics students in a school in Kuala Lumpur. Data from the pilot study was used to run the internal consistency reliability. The reliability of the Mathematics Achievement Test and the Mathematical Creativity Test were calculated. The researcher has observed all the items in the instruments and

established that most of the items were reasonable to be used in the study. Efforts have been done to ensure the validity of the modified and translated version of the instrument.

Ideally, each group should have at least 30 respondents (Gay et al., 2000). Thirty-two students from each school were sampled for the study, where students from one school (called School A in this study) served as the intervention group and the other (School B) as the control group. The 64 students were from the Science stream, and they all came from middle socioeconomic families. The duration of one period was around 40 minutes. This continues for 6 weeks. This study intended a total of fifteen sessions of mathematical creativity approaches tailored for Form Four students and this study attempted to cover as wide an extent as could be expected under the circumstances in the Form Four Mathematics syllabus. The intervention group was taught using MCA, while the control group was taught using CLA. All the participants were enrolled in mathematics classes as part of their school curriculum, and the equal gender ratio was not applied because the researcher was not looking at mathematical creativity and achievement from the gender perspective.

### 3.3 Instrumentation

Over the years, several instruments for measuring mathematical creativity and mathematics achievement have been developed (Kim et al., 2004; Sheffield, 2002). For this study, the Mathematics Achievement Test (MAT) was administered for the pre-and post-test for both groups of participants. The different aspects of mathematical creativity were determined by using the Mathematical Creativity Test (MCT) to evaluate the respondents' fluency, flexibility, originality, and elaboration levels. The problems posed elicited open-ended responses to allow variability in the answers.

*Mathematics Achievement Test (MAT)*. As aforementioned, MAT was used for the pre-test and post-test of both groups of participants. The MAT questions covered problem-solving, critical thinking, estimation, and calculation of mathematical problems, and the students were given an hour to complete the test. A mathematics test expert and two qualified mathematics teachers reviewed and verified the MAT for instrument validity. To determine the reliability of the MCT, a pilot test was conducted at the beginning of the study, and the Cronbach's alpha value was recorded as 0.809, confirming the MCT's reliability. The researcher went through all the items in the instrument and found that the majority of the items were relevant in the local context. Efforts were made to ensure that the instrument was authentic and updated. The articles were translated into Bahasa Malaysia, the national language, so that all the respondents could comprehend the questions and pick their preferred language to determine the best answers. The mathematics achievement scores were measured by adding all the scores of all the questions in MAT. During the intervention period, the students were taught according to the Form 4 mathematics syllabus, and they were tested to assess the effects of the treatment on their mathematics achievement. The test touched on topics such as Quadratic Expressions and Quadratic Equations, Sets, Mathematical Reasoning, and Straight Lines.

*Mathematical Creativity Test (MCT)*. The MCT was used to measure the students' mathematical creativity. It was developed and adapted by Lee et al. (2003), Becker and Shimada (1997), and Kim et al. (1997). The internal reliability coefficient (Cronbach  $\alpha$ ) was 0.843; hence considered a reliable instrument. MCT had a total of five questions, and the students were given 50 minutes to answer all of them. The five open-ended questions used in this study are as follows:

Question 1: Patterns, chains, or sequences of numbers (Becker & Shimada, 1997; and Mann, 2005).

Question 2: Sixteen dot problem (Kim et al., 2004).

Question 3: Polygons problem by (Mann, 2005).

Question 4: Hexagon problem (Kim et al., 2004).

Question 5: Classifying several substantial figure problems (Lee et al., 2003).

This instrument was split into four categories: the total amount of correct answers (fluency), the total amount of different categories in responses (flexibility), the uniqueness of ideas (originality), and the explanation in the responses (elaboration). The four categories are the factors of mathematical

creativity. The total mathematical creativity scores for MCT were measured by adding all the scores of fluency, flexibility, originality, and elaboration scores. The instruments were openly published on the web and reproduced in previous articles (e.g., Forthmann et al., 2020; Mann, 2006). The author has attempted to seek permission for the use of the instruments.

### **3.4 Procedures**

At the start of the research, formal authorisation was granted by the principals of the two targeted schools. The sample of 64 students was equally divided between School A and School B, where the former served as the intervention group and the latter the control group. All the respondents were pre-tested by using MAT to avoid attainment differences between the two groups. In conducting the test, the instruments were distributed to the students concurrently.

After the pre-test, students in the intervention group continued with their Form Four mathematics syllabus, which is about 40 minutes long for each lesson. Then the difference this time is that they were taught the subject using the MCA instead of the traditional approach. For 15 consecutive lessons over six weeks, their maths teacher made use of information communication technology (ICT) tools to improve the students' knowledge through innovative methods. For instance, their teacher used the internet for research, PowerPoint presentations to explain the topics being taught in class, and tablets to keep the students engaged. The teacher was also responsible for motivating the students and not providing them with specific solutions. Although it was intended to include a variety of activities that emphasised creativity, the content of the lessons was organised based on the Form Four syllabus over a six-week duration.

Mathematical creativity was promoted to improve the students' achievement in fluency, flexibility, originality, and elaboration (Kim, 2011). For example, students have posed questions such as 'How many different ways can you solve this equation?', which is aimed at stimulating flexibility. For fluency, they had to come up with several different ways in which mathematical solutions can be extended. Responses to "What if ..." inquiries, for instance, sought to expand methods of addressing mathematical issues through elaborations, justifications, and explanations. The originality component includes answers to questions to develop original ideas. However, in order to develop their higher-level analytical skills, the students were required to think creatively and to connect real-life applications to solve mathematics problems (Haylock, 1997). Students were also encouraged to share mathematical ideas in problem-solving through inquiries, projects, and investigations.

For the control group of students, they were exposed to the CLA, where they were taught mathematics activities that involved group work and discussions. The conventional chalk-and-talk method was used for teaching mathematics (Mignano & Weinstein, 2003). The lesson plan for the control group was developed by the school in line with the Form Four syllabus. The students were also exposed to work drilling and encouraged to provide final fixed solutions to mathematics problems. Traditional instructional practices and textbook references framed the fundamentals of the learning approach for the group (Volk et al., 2017).

Overall, the students in the control group were taught the concept of mathematics by memorising facts, formulas, and methods. They were also required to discuss learning materials according to the syllabus in groups. The conventional group students were unaware of the creative mathematical approach. Data for the study was obtained first from the pre-test and again during the post-test using different approaches.

For mathematics achievement, students from both groups were post-tested with the following tools: MAT, MCT, and Creative Personal Test (CPT). The MCT was administered to evaluate the students' mathematical creativity components, namely fluency, flexibility, uniqueness, and elaboration.

## **4. Data analysis procedure**

An independent sample t-test was done to measure the differences in the scores of mathematics achievement and mathematical creativity among the control group and intervention group students after being exposed to CLA and MCA, respectively. Statistical Package for the Social Sciences (SPSS) was used for data analysis, and findings indicated a violation of the assumptions of normality and homogeneity of variance.

## 5. Findings and results

### 5.1 Descriptive Statistics

The sample of 64 Form Four students was divided equally into two groups, where the intervention group comprises 12 boys and 20 girls, while the control group had 20 boys and 12 girls. Table 2 shows the distribution of the respondents according to grouping and genders.

**Table 2.** Distribution of the frequency and the percentage of respondents.

Group	Boys		Girls	
	Frequency	Percentage	Frequency	Percentage
Control Group	12	37.5	20	62.5
Intervention Group	20	62.5	12	37.5
Total	32	100.0	32	100.0

### *Analysis Based on Research Questions*

**Research Question 1:** Is there any difference in mathematics achievement mean scores between the intervention group, which was taught using MCA, and the control group, which was taught using CLA, after the treatment?

Both pre-test and post-test were used to determine whether there was a significant difference between the control group (using CLA) and the intervention group (using MCA) of the Form Four Students' Mathematics Achievement Test mean scores. The aim of pre-testing the mathematics achievement of the students was to ascertain whether the two groups of students who participated in the study had equivalent achievement in mathematics at the beginning of the study. To achieve this aim, the students in intervention and control groups were pre-tested on Mathematics Achievement Test (MAT). Preliminary analyses were also performed to ensure that no violation of the assumptions of normality, linearity, and homoscedasticity occurred. Based on data analysis of Mathematics Achievement Test scores, the pre-test mean scores for intervention and comparison groups respectively were quite similar. It seems that the mean scores of both groups pre-test did not differ substantially. To evaluate this, an independent samples t-test was carried out to find out whether these means were significantly different and the results are shown in Table 3. In table 3, according to equality of variances based on Levene's test ( $p > 0.05$ ), the variances in both classes were precisely equal.

**Table 3.** Independent Sample Test for MAT Pre-Test.

	Levene's Test for Equality of Variances		t-test for Equality of Means							
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Score	Equal variances assumed	.580	.449	.133	62	.894	.406	3.051	-5.692	6.504
	Equal variances not assumed			.133	60.534	.894	.406	3.051	-5.695	6.507

Also, the results of the t-test revealed that there was no significant difference in the mean score values in the pre-test of MAT between the intervention group ( $M = 69.88$ ,  $SD = 11.21$ ) who were taught using MCA and the control group ( $M = 69.47$ ,  $SD = 13.12$ ) who were exposed to CLA before the treatment ( $t = 0.133$ ,  $df = 62$ ,  $p > 0.05$ ). This indicates that both groups were homogeneous and equivalent. For the control group of students, statistical analysis indicated a significant difference in pre-and post-test ( $t(31) = 1.974$ ,  $p < 0.05$ ) after the treatment. Consequently, after the conventional learning approach was used in the lessons, there was a significant difference in the students' achievement mean scores in mathematics for the control group. To compare the mean scores between the pre-and post-test for the intervention group of students, a paired sample t-test was performed and the results indicated that there was a significant difference between the mean score values ( $t(31) = -2.09$ ,  $p < 0.05$ ). Thus, the findings concluded that MAT had improved the achievement in mathematics among students in the intervention group.

**Table 4:** Independent Sample Test for MAT Post-Test

	Levene's Test for Equality of Variances		t-test for Equality of Means							
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Score	Equal variances assumed	.025	.875	2.979	62	.004	16.281	5.465	5.356	27.206
	Equal variances not assumed			2.979	61.999	.004	16.281	5.465	5.356	27.206

Another independent sample t-test was conducted to find out whether there was a significant difference between the mean scores in the post-test of MAT for the intervention group ( $M = 76.38$ ,  $SD =$

21.83) and the control group ( $M = 60.09$ ,  $SD = 21.89$ ) after the intervention had been conducted. As shown in Table 4, the results indicated that there was a significant difference in the mean score values in the post-test of MAT between the intervention group of students who were taught using MCA and the control group students who were exposed to CLA ( $t = 2.979$ ,  $df = 62$ ,  $p < 0.05$ ). The intervention group exhibited significantly higher mean scores compared to the control group on the correctness of the answers. This finding showed that the intervention group had performed significantly better than the control group.

**Research Question 2:** Is there any difference in the mean scores of mathematical creativity from different aspects: fluency, flexibility, uniqueness, and elaboration between the students who were exposed to MCA and students who were exposed to CLA?

The Mathematical Creativity Test was used to evaluate mathematical creativity in terms of fluency, flexibility, uniqueness, and elaboration. The parametric assumptions were also inspected for the mathematical creativity scores, and Table 5 summarised the inspected parametric assumptions for the independent t-test. In scoring the responses generated by the students, control of the mathematical creativity scores components (fluency, flexibility, uniqueness, and elaboration) for both groups in the Mathematical Creativity Test revealed a significant difference in terms of the mean scores between the intervention group ( $M = 58.03$ ,  $SD = 14.54$ ) and the control group ( $M = 27.41$ ,  $SD = 7.41$ ) after the treatment ( $t = 2.022$ ,  $df = 62$ ,  $p < .05$ ). Besides, the students also displayed a willingness to undertake new tasks, initiate new ideas for classroom activities, and adjust quickly to changes in procedures during the study. The result showed that the students in the intervention group achieved significantly greater mean scores compared to those in the control group on the mathematical creativity scores components. It can also be seen that students in the intervention group ( $M = 27.41$ ,  $SD = 7.41$ ) registered higher mean fluency scores compared to the control group of students ( $M = 23.84$ ,  $SD = 8.13$ ). The flexibility score of students in the intervention group ( $M = 20.09$ ,  $SD = 4.31$ ) was also particularly outstanding compared to those from the control group ( $M = 17.75$ ,  $SD = 4.23$ ) after the intervention. Intervention group students ( $M = 8.22$ ,  $SD = 4.85$ ) were the most successful in producing multiple unique solutions to mathematical creativity problems compared to control group students ( $M = 6.25$ ,  $SD = 5.64$ ). Students in the intervention group ( $M = 2.31$ ,  $SD = 0.47$ ) attained a higher mean score for the elaboration component of the mathematical creativity solutions compared to the control group ( $M = 2.25$ ,  $SD = 0.57$ ). Based on all these findings, it is evident that the intervention group students, who were taught using the MCA, performed better in all the components of mathematical creativity when compared with those from the control group, who were taught using the CLA.

**Table 5.** Independent sample test for MCT.

	Levene's Test for Equality of Variances		t-test for Equality of Means							
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Score	Equal variances assumed	1.342	.251	2.022	62	.047	7.938	3.925	.091	15.784
	Equal variances not assumed			2.022	60.766	.048	7.938	3.925	.088	15.787

**Research Question 3:** Is there any correlation between mathematics achievement and mathematical creativity between the students who were exposed to MCA and students who were exposed to CLA?

The Pearson product-moment correlation coefficient test was utilised to determine the correlation between mathematical creativity and mathematics achievement. Table 6 depicts the value of the Pearson correlation coefficient between scores on the MCT and marks obtained in the MAT for both groups. By using SPSS, for the intervention group, the value of the Pearson correlation when the degree of freedom is 30 is  $\alpha = 0.01$ , which is  $r_{XY} = 0.845$ . For the control group, the value is  $r_{XY} = 0.701$ . Based on Schober & Schwarte (2018), when the Pearson correlation coefficient,  $r$  value is greater than 0, it indicates a positive correlation; as the value of one variable increases, the value of the other variable also increases. The strong correlation between the variables is when the value of Pearson correlation coefficient,  $r$  is more than 0.7, medium correlation when their  $r$  value is between 0.4 to 0.6, and weak correlation when the  $r$  value is less than 0.4 (Akoglu, 2018). Therefore, it can be concluded that there is a positive and very high correlation between mathematics achievement and mathematical creativity for the intervention and the control groups. The aspect of mathematics achievement is in predicting a relationship with mathematical creativity.

**Table 6.** Pearson correlation between Mathematical Creativity and Mathematics Achievement

Variable	N	Pearson correlation coefficient	p-value
Test between mathematics achievement and mathematical creativity	Intervention Group (IG)	0.845	0.000
	Control Group (CG)	0.701	0.000

## 6. Discussion

This research study investigated the applicability and effects of MCA on students' mathematical creativity in terms of fluency, flexibility, uniqueness, and elaboration, and also their mathematics achievement. The findings from this study have added to the body of knowledge in the education field, with a particular focus on the creativity of Form Four mathematics students in Malaysia. This research is also of value as it had investigated the efficacy of MCA.

This research highlighted that the mathematical performance between both groups was significantly different after exposure to MCA. The results revealed that the MCA could help students to enhance mathematics achievement scores. A post-test was carried out for both groups of students to assess whether there were significant differences between students who were taught using MCA and those exposed to CLA after the intervention (Roslan et al., 2007). The findings showed that there was a statistically significant difference in mathematics achievement between the different groups of students after the treatment. Thus, there was an effect of MCA on the mathematics achievement mean scores of the students. The results of the study corresponded to those that show that MCA was important in enhancing mathematics achievement (Gajda et al., 2017).

The results also showed that there was a significant difference in mathematical creativity mean score between the intervention group after being exposed to MCA compared with the control group after exposure to CLA. The findings also indicated the successful integration of MCA to promote mathematical creativity among students. Educators could, therefore, adopt the learning approaches of MCA since the findings showed the statistically significant effects of mathematics lessons that incorporate MCA on students' mathematical creativities. These results are consistent with the findings of earlier research that also discovered the effectiveness of MCA in improving mathematical creativity (Cilli-Turner et al., 2021; Haavold, 2021; Maulidia et al., 2019; Fetterly, 2010; Delis et al., 2007; Silver, 1997). Pearson's coefficient of correlation also showed that the academic achievement and mathematical creativity scores were consistent with past studies (Kozlowski & Si, 2019; Regier & Savic, 2020; Schoevers et al., 2020; Suyitno, 2020; Weinhandl & Lavicza, 2021; Mann, 2005). This indicated that creative practices in the classrooms could benefit mathematics students.

## 7. Conclusion

The results of this study show that MCA is more efficient than CLA to improve students' productivity, too. This means that the use of MCA enhances the performances of students in solving mathematical problems, leading to higher mathematics achievement scores. It is, therefore, recommended that MCA be used in schools because it can enhance students' mathematical imagination, differences of opinion, inspiration and increase their interest in mathematics. Exposing students to MCA, which emphasises fluency, flexibility, originality, and elaboration, will spur higher-order thinking skills. Although this study involved secondary school students only, the findings indicated that MCA may also be beneficial for those pursuing higher education. It may serve as a guide for teacher educators in institutions of higher learning to design innovative curriculum for pre-service mathematics teachers, especially those being trained to integrate creativity and character development into student learning.

## 8. References

- Aizikovitsh-Udi, E. (2014). The extent of mathematical creativity and Aesthetics in solving problems among students attending the mathematically talented youth program. *Creative Education*, 5(4), 228–241. doi: 10.4236/ce.2014.54032
- Akoglu, H. (2018). User's guide to correlation coefficients. In *Turkish Journal of Emergency Medicine*. doi: 10.1016/j.tjem.2018.08.001.
- Barraza-García, Z. M., Romo-Vázquez, A., & Roa-Fuentes, S. (2020). A theoretical model for the development of mathematical talent through mathematical creativity. *Education Sciences*. doi: 10.3390/educsci10040118.
- Becker, J. P., & Shimada, S. (1997). *The Open-Ended Approach: A New Proposal for Teaching Mathematics*. ERIC.
- Cilli-Turner, E., Savić, M., Tang, G., Turkey, H. El, & Karakok, G. (2021). *Sources of evolution of*

- university students' views on mathematical creativity. doi: 10.51272/pmena.42.2020-168
- Creswell, J. W. (2008). *Educational research: planning, conducting and evaluating quantitative and qualitative research*. Upper Saddle River, New Jersey: Pearson Education Inc.
- Cohen, L.; Manion, L.; & Morrison, K. (2000). *Research methods in education*. 5<sup>th</sup> edition. London: Routledge Falmer.
- Delis, D. C., Lansing, A., Houston, W. S., Wetter, S., Han, S. D., Jacobson, M., Holdnack, J., & Kramer, J. (2007). Creativity lost: The importance of testing higher-level executive functions in school-age children and adolescents. *Journal of Psychoeducational Assessment*, 25(1), 29–40. doi: 10.1177/0734282906292403
- Fetterly, J. M. (2010). *Exploratory Study of the Use of a Problem-Posing Approach on Pre-Service Elementary Education Teachers' Mathematical Creativity, Beliefs, and Anxiety* [Ph.D. Thesis]. The Florida State University.
- Forthmann, B., Paek, S. H., Dumas, D., Barbot, B., & Holling, H. (2020). Scrutinizing the basis of originality in divergent thinking tests: On the measurement precision of response propensity estimates. *British Journal of Educational Psychology*, 90(3), 683–699.
- Fraenkel, J.R., Wallen, N.E., & Hyun, H.H. (2011). *How to design and evaluate research in education*. New York: McGraw Hill.
- Gajda, A., Karwowski, M., & Beghetto, R. A. (2017). Creativity and academic achievement: A meta-analysis. *Journal of Educational Psychology*, 109(2), 269–299. doi:10.1037/edu0000133
- Gay, L.R. and P. Airasian, 2000. *Educational research: Competencies for analysis and application*. New York: Wiley. Jersey: Prentice-Hall.
- Ghazali, N., Nordin, M. S., Abdullah, A., & Ayub, A. F. M. (2020). The relationship between students' MOOC-efficacy and meaningful learning. *Asian Journal of University Education*, 16(3), 89–101. doi: 10.24191/ajue.v16i3.11071
- Graziano, A. M., & Raulin, M. L. (2010). *Research Methods, A Process of Inquiry* (7th ed.). Pearson Education Inc.
- Haylock, D. (1997). Recognising mathematical creativity in schoolchildren. *ZDM*, 29(3), 68–74. doi: 10.1007/s11858-997-0002-y
- Haavold, Ø. (2021). Impediments to mathematical creativity: Fixation and flexibility in proof validation. In *The Mathematics Enthusiast*.
- Hosseini, A. S., & Watt, A. P. (2010). The effect of a teacher professional development in facilitating students creativity. *Educational Research and Reviews*, 5(8), 432–438.
- Huang, P.-S., Peng, S.-L., Chen, H.-C., Tseng, L.-C., & Hsu, L.-C. (2017). The relative influences of domain knowledge and domain-general divergent thinking on scientific creativity and mathematical creativity. *Thinking Skills and Creativity*, 25, 1–9.
- Isnani, Waluya, S. B., Rochmad, & Wardono. (2020). Analysis of mathematical creativity in mathematics learning is open ended. *Journal of Physics: Conference Series*. doi: 10.1088/1742-6596/1511/1/012102.
- Johnson, D. T. (2000). *Teaching mathematics to gifted students in a mixed-ability classroom*. ERIC Clearinghouse on Disabilities and Gifted Education.
- Kaplan, D. (2019) Creativity in Education: Teaching for Creativity Development. *Psychology*, 10, 140–147. doi: 10.4236/psych.2019.102012.
- Khalid, M., Saad, S., Hamid, S. R. A., Abdullah, M. R., Ibrahim, H., & Shahrill, M. (2020). Enhancing creativity and problem solving skills through creative problem solving in teaching mathematics. *Creativity Studies*, 13(2), 270–291. doi: 10.3846/cs.2020.11027
- Kim, H., Cho, S., & Ahn, D. (2004). Development of mathematical creative problem solving ability test for identification of the gifted in math. *Gifted Education International*, 18(2), 164–174. doi: 10.1177/026142940301800206
- Kim, K. H. (2011). The creativity crisis: The decrease in creative thinking scores on the Torrance Tests of Creative Thinking. *Creativity Research Journal*, 23(4), 285–295.
- Kim, S.-E., Hwang, B.-Y., Kim, Y.-H., Kim, Y.-C., Lee, K.-S., & Lee, J.-J. (1997). Multidrug-resistance reversing activity of medicinal plants. *Korean Journal of Pharmacognosy*, 28(4), 174–178.
- Kozlowski, J. S., Chamberlin, S. A., & Mann, E. (2019). Factors that influence mathematical creativity.

*Mathematics Enthusiast.*

- Lee, A. R., & Bailey, D. R. (2020). Examining South Korean University Students' Interactions with International Students. *Asian Journal of University Education*, 16(3), 43–58.
- Lee, K. S., Hwang, D. J., & Seo, J. J. (2003). A Study on the Relationship between General Creativity and Mathematical Creativity-Based on the TTCT; Figural A and the MCPSAT; A. *J. Korea Soc. Math. Educ. Ser. A Mathematics Education*, 42(1), 1–9.
- Leviton, L. C. (2015). External Validity. In *International Encyclopedia of the Social & Behavioral Sciences: Second Edition*. doi: 10.1016/B978-0-08-097086-8.44025-0.
- Mann, E. L. (2006). Creativity: The essence of mathematics. *Journal for the Education of the Gifted*, 30(2), 236–260.
- Mann, E. L. (2005). *Mathematical creativity and school mathematics: Indicators of mathematical creativity in middle school students*. University of Connecticut.
- Maulidia, F., Johar, R., & Andariah, A. (2019). A Case Study Of Students' Creativity In Solving Mathematical Problems Through Problem Based Learning. *Infinity Journal*. doi: 10.22460/infinity.v8i1.p1-10.
- Mignano, A. J., & Weinstein, C. S. (2003). *Elementary classroom management*. McGraw.
- MOE. (2015). *Malaysia Education Blueprint 2015-2025 (Higher education)* (pp. 1–13). Ministry of Education Malaysia. [https://www.um.edu.my/docs/default-source/about-um\\_document/media-centre/um-magazine/4-executive-summary-pppm-2015-2025.pdf](https://www.um.edu.my/docs/default-source/about-um_document/media-centre/um-magazine/4-executive-summary-pppm-2015-2025.pdf)
- Muda, A. L., & Fook, C. Y. (2020). Psychological empowerment and organisational commitment among academic staff of public universities in Malaysia. *Asian Journal of University Education*, 16(2), 26–35.
- Pitta-Pantazi, D., Sophocleous, P., & Christou, C. (2013). Spatial visualizers, object visualizers and verbalizers: Their mathematical creative abilities. *ZDM*, 45(2), 199–213.
- Regier, P., & Savic, M. (2020). How teaching to foster mathematical creativity may impact student self-efficacy for proving. *Journal of Mathematical Behavior*. doi: 10.1016/j.jmathb.2019.100720
- Richardson, C., & Mishra, P. (2018). Learning environments that support student creativity: Developing the SCALE. *Thinking Skills and Creativity*, 27, 45-54. doi: 10.1016/j.tsc.2017.11.004
- Roslan, S., King, J. H. H., Mahyudin, R. H., & Tarmizi, R. A. (2007). The Relationship between Mathematics Self-Efficacy and Mathematics Achievement. *Pertanika Journal of Social Sciences & Humanities*, 15(1), 43–49.
- Roslan, S., Hasan, S., Zaremohzzabieh, Z., & Arsad, N. M. (2021). Big five personality traits as predictors of systems thinking ability of upper secondary school students. *Social Sciences and Humanities*, 29(S1), 251 - 269. doi: 10.47836/pjssh.29.s1.14
- Schober, P., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use and interpretation. *Anesthesia and Analgesia*. doi: 10.1213/ANE.0000000000002864.
- Schoevers, E. M., Kroesbergen, E. H., & Kattou, M. (2020). Mathematical Creativity: A Combination of Domain-general Creative and Domain-specific Mathematical Skills. *Journal of Creative Behavior*. <https://doi.org/10.1002/jocb.361>.
- Sheffield, L. J. (2002). *Extending the challenge in mathematics: Developing mathematical promise in K-8 students*. Corwin press.
- Silver, E. A. (1997). Fostering creativity through instruction rich in mathematical problem solving and problem posing. *Zdm*, 29(3), 75–80.
- Silvia, P. J., Beaty, R. E., & Nusbaum, E. C. (2013). Verbal fluency and creativity: general and specific contributions of broad retrieval ability (Gr) factors to divergent thinking. *Intelligence*, 41, 328–340.
- Sternberg, R. J. (2006). The nature of creativity. *Creativity Research Journal*, 18(1), 87–98.
- Suyitno, A. (2020). Growth of student mathematical creativity as part of 4C competence for entering the 21st century. *Journal of Physics: Conference Series*. <https://doi.org/10.1088/1742-6596/1567/2/022100>.
- Tubb, A. L., Cromptley, D. H., Marrone, R. L., Patston, T., & Kaufman, J. C. (2020). The development of mathematical creativity across high school: Increasing, decreasing, or both? *Thinking Skills and Creativity*. <https://doi.org/10.1016/j.tsc.2020.100634>.

- Volk, M., Cotič, M., Zajc, M., & Starcic, A. I. (2017). Tablet-based cross-curricular maths vs. Traditional maths classroom practice for higher-order learning outcomes. *Computers & Education, 114*, 1–23.
- Weinhandl, R., & Lavicza, Z. (2021). Real-World Modelling to Increase Mathematical Creativity. *Journal of Humanistic Mathematics*. <https://doi.org/10.5642/jhummath.202101.13>.