



THE EFFECT OF OUTDOOR-BASED STEM LEARNING ON STUDENTS MATHEMATICAL CREATIVITY

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Abstract

The rapid development of 21st-century education requires students to possess creativity and higher-order thinking skills. However, mathematics learning in schools is still dominated by conventional approaches that limit students' opportunities to explore ideas and solve problems creatively. This study aimed to analyze the effect of STEM-based outdoor learning on students' mathematical creativity. The research employed a quantitative quasi-experimental design with a nonequivalent control group. The participants were 30 eighth-grade students from MTs Assa'adah, comprising 15 in the experimental class and 15 in the control class. Data were collected using open-ended essay tests based on indicators of mathematical creativity, namely fluency, flexibility, originality, and elaboration. The data were analyzed using N-Gain and the Independent Sample t-test. The results showed that the average posttest score of the experimental class was 83.93, while the control class was 66.73. The average N-Gain score of the experimental class was 0.786 in the high category, whereas the control class obtained 0.556 in the medium category. Hypothesis testing indicated a significant difference between the two groups with a t-count value of 16.734 and a significance value of 0.000 ($p < 0.05$). These findings indicate that STEM-based outdoor learning is more effective in improving students' mathematical creativity than conventional learning.

Keywords: *Mathematical Creativity; Outdoor Learning; STEM*

Abstrak

Perkembangan pendidikan abad ke-21 menuntut siswa memiliki kemampuan berpikir kreatif dan keterampilan berpikir tingkat tinggi. Namun, pembelajaran matematika di sekolah masih didominasi oleh pendekatan konvensional yang membatasi kesempatan siswa untuk mengeksplorasi ide dan menyelesaikan masalah secara kreatif. Penelitian ini bertujuan untuk menganalisis pengaruh pembelajaran STEM berbasis *outdoor learning* terhadap kreativitas matematis siswa. Penelitian menggunakan pendekatan kuantitatif dengan metode *quasi-experiment melalui desain non-equivalent control group*. Subjek penelitian terdiri atas 30 siswa kelas VIII MTs Assa'adah, yaitu 15 siswa pada kelas eksperimen dan 15 siswa pada kelas kontrol. Pengumpulan data dilakukan menggunakan tes uraian *open-ended* berdasarkan indikator kreativitas matematis yang meliputi kelancaran, keluwesan, keaslian, dan elaborasi. Analisis data dilakukan menggunakan *N-Gain* dan *Independent Sample t-test*. Hasil penelitian menunjukkan bahwa rata-rata nilai *posttest* kelas eksperimen sebesar 83,93, sedangkan kelas kontrol sebesar 66,73. Nilai rata-rata *N-Gain* kelas eksperimen sebesar 0,786 dengan kategori tinggi, sedangkan kelas kontrol sebesar 0,556 dengan kategori sedang. Hasil uji hipotesis menunjukkan terdapat perbedaan yang signifikan antara kedua kelompok dengan nilai *t hitung* sebesar 16,734 dan signifikansi sebesar 0,000 ($p < 0,05$). Temuan tersebut menunjukkan bahwa pembelajaran STEM berbasis *outdoor learning* lebih efektif dalam meningkatkan kreativitas matematis siswa dibandingkan dengan pembelajaran konvensional.

Kata kunci: Kreativitas Matematis; Pembelajaran Luar Kelas; STEM

INTRODUCTION

Mathematical creativity is considered one of the essential competencies that students need to develop in the 21st-century learning era. This competency enables students to generate various problem-solving strategies, develop innovative ideas, and relate mathematical concepts to real-life situations (Whitney-Smith et al., 2022). In mathematics education, creativity is not merely associated with

obtaining correct answers, but also with the ability to produce flexible, diverse, and original solutions. Therefore, fostering students' mathematical creativity has become an important objective in mathematics learning (Osakwe et al., 2022).

However, mathematics learning practices in Indonesia still encounter several challenges. Learning activities are generally teacher-centred and dominated by lecturing methods and routine exercises (Muhammad et al., 2023). Students tend to imitate procedures demonstrated by teachers without being encouraged to explore ideas or discover alternative strategies in solving problems (Hodgson & Wilkie, 2022). Consequently, students' creative thinking skills have not been optimally developed (Yang et al., 2023). Mathematics is often perceived as an abstract and difficult subject with limited relevance to everyday life, which ultimately affects students' learning motivation and engagement (Roche et al., 2023).

One learning approach that is considered effective in enhancing students' creativity is the STEM (Science, Technology, Engineering, and Mathematics) approach. STEM emphasizes the integration of multiple disciplines in solving contextual and real-world problems, allowing students to engage actively, collaboratively, and experientially in the learning process (Jurdak, 2016; Dare et al., 2021). Arsy & Syamsulrizal (2021) stated that STEM-based learning can improve students' critical thinking, creativity, and problem-solving abilities because students are positioned as active participants in the learning process. Bybee (2013) defined STEM as an instructional approach that integrates science, technology, engineering, and mathematics into a unified learning experience aimed at helping students solve real-world problems critically and creatively. Similarly, Sanders (2009) explained that STEM is an interdisciplinary approach that connects academic concepts with real-life contexts through project-based activities and problem-solving processes. The characteristics of STEM learning include contextual problem-based learning, interdisciplinary integration, exploratory and collaborative activities, and the application of concepts in everyday life (Dare et al., 2021; Smith et al., 2022). In mathematics learning, STEM is closely related to mathematical creativity because it encourages students to think flexibly, generate multiple solution alternatives, and connect mathematical concepts with contextual situations (Mierluș-Mazilu & Yilmaz, 2023; Nilimaa, 2023).

In addition to STEM, outdoor learning is another approach that has considerable potential to improve the quality of mathematics learning. Outdoor learning utilizes the surrounding environment as a learning resource, enabling students to gain direct experiences through observation, measurement, exploration, and problem-solving activities in authentic contexts. Environment-based learning helps students understand mathematical concepts in more concrete and meaningful ways. Through direct interaction with the environment, students are also encouraged to develop divergent thinking skills and creativity. The implementation of outdoor learning is closely associated with Kolb's experiential learning theory (1984), which emphasizes that knowledge is constructed through direct experiences involving observing, experimenting, reflecting, and applying experiences to new situations. In mathematics learning, outdoor learning is highly relevant because many mathematical concepts can be identified in daily life, such as measurement, geometric forms, patterns, and statistics. Learning activities conducted outside the classroom can help students understand mathematical concepts more concretely and meaningfully, thereby supporting the development of creativity and divergent thinking skills.

Several previous studies have demonstrated the effectiveness of STEM-based learning in improving students' creative thinking skills. Nasution et al. (2024) found that STEM-based Project-Based Learning positively influenced students' creativity and learning outcomes. Similarly, Fitriyah et al. (2021) reported that STEM integration enhanced students' creative thinking abilities in mathematics learning. Furthermore, studies related to outdoor learning revealed that environment-based learning could increase student engagement, critical thinking skills, and conceptual understanding in

mathematics. Dewi et al. (2023) showed that STEM-based Project-Based Learning significantly improved students' creativity and learning outcomes because students were directly involved in exploration and project-based problem-solving processes. In addition, Munawaroh et al. (2025) found that outdoor learning enhanced student participation and helped students understand mathematical concepts more concretely through direct learning experiences.

Based on these studies, STEM primarily focuses on interdisciplinary integration and creative problem-solving, whereas outdoor learning emphasizes direct learning experiences through real-world environments. Therefore, integrating STEM with outdoor learning has the potential to create mathematics learning experiences that are more contextual, meaningful, and effective in fostering students' mathematical creativity. Nevertheless, studies integrating STEM and outdoor learning in mathematics education remain limited. Most previous studies have investigated STEM and outdoor learning separately. In fact, the integration of these two approaches may create more contextual, exploratory, and meaningful learning experiences. Combining STEM with outdoor learning allows students not only to understand mathematical concepts theoretically but also to apply them directly in real-life situations.

The novelty of this study lies in the integration of the STEM approach and outdoor learning in mathematics instruction to improve junior high school students' mathematical creativity, an area that has rarely been explored in previous research. Preliminary observations conducted at MTs Assa'adah indicated that students' mathematical creativity was still relatively low. Most students tended to use only one strategy in solving mathematical problems and experienced difficulties when confronted with open-ended problems requiring multiple solution alternatives. This condition suggests that mathematics learning has not yet provided sufficient opportunities for students to develop creativity. Based on these issues, an innovative and contextual learning approach is needed to improve students' mathematical creativity. Therefore, this study aims to analyze the effect of STEM-based outdoor learning on students' mathematical creativity.

METHOD

This study investigated the effect of STEM-based outdoor learning on students' mathematical creativity using a quantitative approach with a quasi-experimental method. The study employed a non-equivalent control group pretest-posttest design involving an experimental group and a control group without random assignment of subjects. A total of 30 eighth-grade students participated in this study, which was conducted at MTs Assa'adah during the second semester of the 2025–2026 academic year. Class VIII A, consisting of 15 students, was assigned as the experimental group, while Class VIII B, consisting of 15 students, served as the control group. The sample was selected using purposive sampling based on the similarity of students' abilities (Astuti, 2016). The research procedure was carried out through several stages. First, two classes with relatively equivalent abilities were selected. Second, a pretest was administered to both groups to measure students' initial mathematical creativity. Third, the experimental group received STEM-based outdoor learning instruction, whereas the control group was taught using conventional learning methods. Fourth, a posttest was administered to both groups to measure students' final mathematical creativity. Finally, the collected data were processed and analyzed to determine the effect of the implemented learning approach. The research design used in this study is presented in Table 1.

Table 1. Non-Equivalent Control Group Research Design

Group	Pretest	Treatment	Posttest
Experimental Group	O_1	X	O_2
Control Group	O_3	—	O_4

Notes:

O_1 and O_3 : Pretest Results of the Experimental and Control Groups

O_2 and O_4 : Posttest Results Following the Treatment
 X : Treatment in the Form of STEM-Based Outdoor Learning Instruction

The independent variable in this study was STEM-based outdoor learning, while the dependent variable was students' mathematical creativity. The research instrument consisted of open-ended essay tests developed based on the indicators of mathematical creativity, including: (1) fluency, (2) flexibility, (3) originality, and (4) elaboration. Before its implementation, the instrument was validated through expert judgment involving two mathematics education lecturers and one mathematics teacher. The validation results indicated that the instrument was appropriate for use. Furthermore, the reliability test using Cronbach's Alpha produced a coefficient of 0.82, indicating that the instrument had high reliability. The following are examples of open-ended questions used in the study:

Test Questions

The mathematics test scores of 10 eighth-grade students are presented as follows:

65, 70, 75, 75, 80, 80, 85, 90, 90, 95

Answer the following questions carefully!

- Calculate the mean, median, and mode of the data above.
- Recalculate the mean or median using a different method from the first one.
- Use the method that you consider the most unique or different to determine either the mean, median, or mode.
- Explain your solution process clearly and systematically from beginning to end.

Figure 1. Example of an Open-Ended Question

The scoring rubric was developed based on the indicators of mathematical creativity, with a score range of 0–25 for each indicator. Data analysis was conducted using Microsoft Excel and IBM SPSS version 25. The analysis began with the presentation of descriptive statistics for both the experimental and control groups, including pretest and posttest results. Subsequently, the N-Gain scores of the experimental and control groups were calculated using the formula presented in Equation 1.

$$N - Gain (g) = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score} \quad (1)$$

The improvement in students' mathematical creativity was analyzed using the N-Gain index (g), as presented in Table 2.

Table 2. N-Gain Classification Criteria

Average N-Gain Score	N-Gain Category
$g > 0,70$	High
$0,30 \leq g \leq 0,70$	Moderate
$0 < g < 0,30$	Low
$g \leq 0$	Filed

The next stage involved conducting prerequisite tests and hypothesis testing. The prerequisite tests consisted of a normality test using the Kolmogorov–Smirnov test and a homogeneity test using Levene's test (Ningsih & Astuti, 2024). Furthermore, hypothesis testing was conducted using an independent samples t-test to determine the difference in the mean scores of mathematical creativity between the experimental group and the control group. The formula used in the analysis is presented in Equation (2).

$$t_{hitung} = \frac{M_1 - M_2}{\sqrt{\frac{SS_1 + SS_2}{n_1 + n_2 - 2} \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}} \quad (2)$$

where:

- M_1 : represents the mean score of students' mathematical creativity in the experimental group.
 M_2 : represents the mean score of students' mathematical creativity in the control group.
 SS_1 : represents the sum of squared deviations in the experimental group.
 SS_2 : represents the sum of squared deviations in the control group.
 n_1 : represents the number of students in the experimental group.
 n_2 : represents the number of students in the control group.

The decision-making criterion used a significance level of $\alpha = 0.05$, where H_0 was rejected if the p-value ≤ 0.05 and H_0 was accepted if the p-value > 0.05 . This quasi-experimental design was selected because it allows the direct examination of treatment effects in naturally formed classroom settings. Therefore, the findings can provide a realistic description of the effectiveness of implementing STEM-based outdoor learning in the context of mathematics instruction.

RESULTS AND DISCUSSION

Pretest Results

The experimental group received STEM-based outdoor learning instruction, while the control group was taught using conventional learning methods. The learning process was conducted over four meetings using the same instructional material for both groups. The analyzed data consisted of students' mathematical creativity test results in the form of pretest and posttest scores from both the experimental and control groups. The pretest results indicated that the initial abilities of both groups were relatively equivalent. The descriptive analysis of the pretest data is presented in Figure 2.

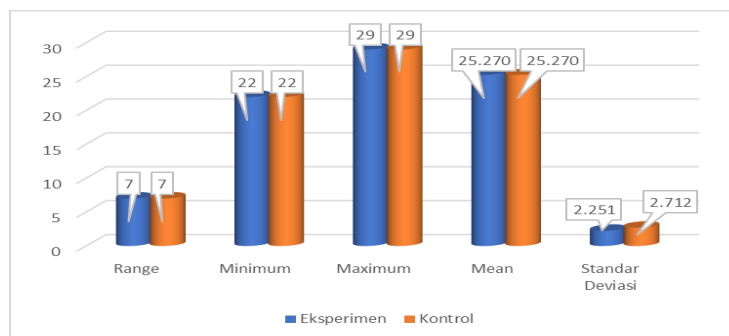


Figure 2. Descriptive Statistics of Pretest Data

The pretest results showed that the students' initial mathematical creativity abilities in both groups were relatively equivalent. The experimental group obtained a mean pretest score of 25.27 with a standard deviation of 2.25, while the control group obtained a mean score of 25.27 with a standard deviation of 2.71. These findings indicate that both groups had comparable initial abilities before the treatment was administered.

Posttest Results

The posttest results revealed a significant difference between the two groups. A descriptive summary of the posttest results of the experimental and control groups is illustrated in Figure 3.

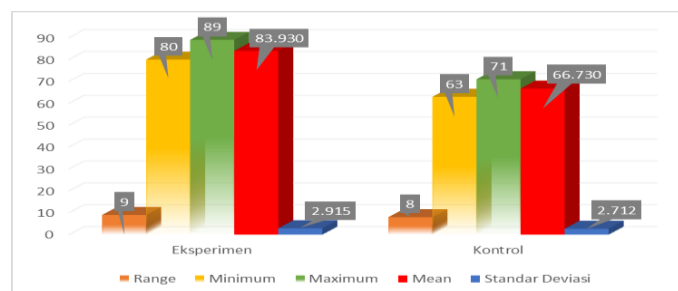


Figure 3. Descriptive Statistics of Posttest Data

Figure 3 shows that after the treatment was administered, there was an improvement in mathematical creativity in both groups. The experimental group obtained a mean posttest score of 83.93 with a standard deviation of 2.91, whereas the control group obtained a mean score of 66.73 with a standard deviation of 2.71. The difference in the mean scores indicates that STEM-based outdoor learning had a greater effect on students' mathematical creativity compared to conventional learning.

N-Gain Score Analysis

The N-Gain test was used to determine the extent of improvement in students' mathematical creativity before instruction (pretest) and after instruction (posttest) in each group. This analysis aimed to examine the effectiveness of the implementation of STEM-based outdoor learning in improving students' creativity. The descriptive statistics of the N-Gain scores are presented in Figure 3.

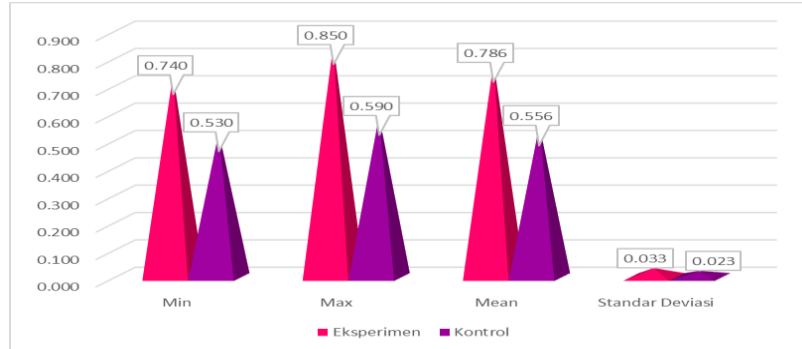


Figure 3. Descriptive Statistics for N-Gain Scores

Figure 3 illustrates the N-Gain analysis results, which showed that the average improvement in students' mathematical creativity in the experimental group was 0.786, categorized as high, while the control group obtained an average score of 0.556, categorized as moderate. These findings indicate that the improvement in students' mathematical creativity in the experimental group was greater than that of the control group.

Prerequisite Tests

Normality Test

The results of the normality test using the Shapiro–Wilk test showed that all data had significance values greater than 0.05, indicating that the data were normally distributed. The results of the normality test are presented in Table 3.

Table 3. Results of the Normality Test

Class	Shapiro-Wik	
	grade	<i>p-value</i>
Experimental pretest	0,951	0,539
Experimental posttest	0,946	0,468
Control pretest	0,951	0,539
Control posttest	0,926	0,237

The results indicate that the pretest and posttest data of both the experimental and control groups were normally distributed.

Homogeneity Test

The results of the homogeneity test using Levene's Test showed a significance value of 0.849 > 0.05. This finding indicates that the variances of the two groups were homogeneous. The results of the homogeneity test are presented in Table 4.

Table 4. Results of the Homogeneity Test

	Levene Statistic	df1	df2	<i>p-value</i>
Based on mean	0,037	1	28	0,849

Hypothesis Testing

Independent Samples t-Test

The results of the Independent Samples t-test on the N-Gain scores revealed a t-value of 16.734 with a significance value of 0.000 ($p < 0.05$). Since the significance value was lower than 0.05, H_0 was rejected, and H_1 was accepted. These findings indicate that there was a statistically significant difference in the improvement of mathematical creativity between students who received STEM-based outdoor learning and those who were taught using conventional learning methods. The results of the hypothesis testing are presented in Table 5.

Table 5. Results of the t-test

	df	estimasi	Standard error	t-stat	Sig. 2- tailed
Equal variances assumed	28	17,200	1,028	16,734	0,000

The increase in mathematical creativity among students in the experimental class indicates that STEM learning based on outdoor learning is capable of creating a more contextual and exploratory learning experience. Through observation, discussion, and real-world problem-solving activities in their immediate surroundings, students have the opportunity to develop a variety of creative problem-solving strategies.

Discussion

The results of this study showed that STEM-based outdoor learning was more effective in improving students' mathematical creativity than conventional learning. The improvement occurred because students were actively involved in exploration, observation, and problem-solving activities related to real situations in the surrounding environment (Karamustafaoğlu & Pektaş, 2023). Through direct learning experiences, students had more opportunities to develop ideas and discover various strategies for solving mathematical problems. The STEM-based outdoor learning approach theoretically encourages the development of divergent thinking skills through exploratory and collaborative learning activities (Wulandari et al., 2026). In the learning process, students were not only passive recipients of information from the teacher, but they also actively constructed knowledge through direct experiences (Anthony, 1996). Activities such as observing the environment, measuring real objects, and conducting group discussions enabled students to produce various alternative solutions to mathematical problems (Nilimaa, 2023). This condition contributed to the improvement of students' mathematical creativity.

Outdoor learning is also closely related to experiential learning theory proposed by Kolb (1984), which emphasizes that knowledge is developed through direct experiences involving observation, experimentation, reflection, and application. In mathematics learning, outdoor learning helps students understand mathematical concepts more concretely and contextually because students can directly connect mathematical theories with everyday situations (Priyadi, 2021). As a result, students become more flexible and creative in solving problems. The findings of this study are consistent with previous studies. Arsy and Syamsulrizal (2021) reported that STEM-based learning could improve students' creativity and thinking skills. Similarly, Manungki and Manahung (2021) found that environment-based learning increased students' engagement and participation in the learning process. Therefore, the integration of STEM and outdoor learning can create more meaningful and contextual mathematics learning experiences for students (Pitiporntapin et al., 2025). The novelty of this study lies in the integration of STEM and outdoor learning approaches in mathematics instruction. Previous studies generally examined STEM and outdoor learning separately, whereas this study combined both approaches to improve students' mathematical creativity. The findings indicate that the combination of these approaches can support more innovative and student-centered learning (Capone, 2022; binti Zakeri et al., 2023; Kwon & Lee, 2025).

Practically, the results of this study can serve as an alternative reference for teachers in designing innovative mathematics learning activities (Albai & Eisma, 2025). STEM-based outdoor learning can help students improve their creativity, participation, and confidence in solving mathematical problems (Karamustafaoğlu & Pektaş, 2023). However, this study has several limitations, including the small number of participants, the limited duration of the research, and the implementation of the study in only one school. Therefore, future researchers are recommended to involve larger samples and different educational levels in order to obtain more comprehensive and generalizable findings.

CONCLUSION

The findings of this study indicate that STEM-based outdoor learning had a significant effect on students' mathematical creativity. The results showed that the average N-Gain score of the experimental group was 0.786, which was categorized as high, while the control group obtained an average N-Gain score of 0.556, which was categorized as moderate. The hypothesis testing result revealed a significance value of 0.000 ($p < 0.05$) and a t-count value of 16.734, indicating a significant difference in the improvement of mathematical creativity between the two groups. Therefore, STEM-based outdoor learning was proven to be more effective than conventional learning in improving students' mathematical creativity.

Mathematics teachers are recommended to implement STEM-based outdoor learning as an alternative instructional approach to enhance students' creativity and engagement in mathematics learning. Schools are also expected to provide adequate facilities and supportive learning environments to facilitate the implementation of outdoor learning activities. Future studies are recommended to involve larger sample sizes, longer research durations, and additional variables such as critical thinking skills, numeracy literacy, and problem-solving abilities in order to obtain more comprehensive research findings.

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