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Article

The Effect of Outdoor Learning Math Using Gps-Based Mobile Technology-Assisted Mathematics Traces on Junior High School Students' Problem-Solving Ability and Mathematical Communication Skills

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Abstract: The purpose of this study is to describe the effect of Outdoor Learning Math using GPS-based mobile technology-assisted math traces on students' problem solving and mathematical communication skills, describe the effect of Outdoor Learning Math using GPS-based mobile technology-assisted math traces on problem solving skills, and describe the effect of Outdoor Learning Math using GPS-based mobile technology-assisted math traces on students' mathematical communication skills. This type of research is Quasi Experimental using Nonequivalent Control Group Design. This research was conducted at SMP Negeri 1 Malinau, North Kalimantan City with 60 students from two 9th grade classes. The instruments used in this study were descriptive test questions of problem solving ability, mathematical communication and observation sheets for the implementation of Outdoor Learning Math learning activities using GPS-based mobile technology-assisted math traces. The results showed that there was an effect of Outdoor Learning Math using GPS-based mobile technology-assisted math traces on students' problem solving and mathematical communication skills together, there was no effect of Outdoor Learning Math using mobile technology-assisted math traces on problem solving skills, and there was no effect of Outdoor Learning Math using GPS-based mobile technology-assisted math traces on mathematical communication skills. Therefore, for future researchers to expand the scope of materials such as geometry, statistics and probability, algebra, arithmetic and add student motivation variables.

Keywords: Mathematical Communication Ability; Problem Solving Ability; Math Trail; Mobile Technology; Outdoor Learning Math

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1. Introduction

21st century education requires critical thinking, communication, and the application of technology. Mathematics as an important subject in modern education is required to be able to improve students' problem-solving and mathematical communication skills. However, the reality on the ground shows that this ability is still low. Based on Anisa's (2014) study, only 10.15% of students are able to solve problems and 17.77% have adequate mathematical communication skills. A similar condition occurred at SMP Negeri 1 Malinau Kota, where students had difficulty in solving contextual problems and conveying ideas mathematically.

One of the causes of this low ability is the conventional learning model that is still teacher-centered and does not involve technology and contextual activities. In addition, the use of the internet by students is more for games than for learning (Hadisaputra et al., 2022).

As a solution, the *Outdoor Learning Math* approach by utilizing *math traces assisted by GPS-based mobile technology* is an innovative alternative. This model combines pedagogic, content, and technological elements within the framework of TPACK (Hanik et al., 2022). This

method takes students outside the classroom to solve real problems by using mobile applications equipped with maps, instructions, and live feedback (Cahyono & Ludwig, 2016; Ludwig et al., 2015).

In addition to increasing learning motivation, this method also facilitates mathematical modeling, group cooperation, and the ability to connect mathematical concepts with the real world. Thus, this approach is believed to improve students' problem-solving and mathematical communication skills. This study was conducted to empirically test the influence of this approach on junior high school students in grade IX with tube material.

2. Literature Review

2.1. Mathematics and Mathematics Learning

Mathematics is a science related to numbers, structures, spaces, and changes. In the Great Dictionary of the Indonesian Language, mathematics is defined as the science of numbers and the relationships between numbers and the operational procedures used in solving them. Furthermore, the Ministry of Education and Culture (2017) stated that mathematics is the result of abstraction of surrounding objects that are used to solve real-life problems. Gusteti et al. (2022) reinforce that mathematics is a tool for thinking, communicating, and solving problems.

Mathematics learning does not only focus on mastering formulas, but on the ability to think critically and solve contextual problems (Gusteti et al., 2022; Wahyuningsih & Amidi, 2023). This process involves interaction between teachers and students that aims to develop students' cognitive, affective, and psychomotor abilities in the context of mathematics.

2.2 Outdoor Learning Math

Outdoor Learning Math is a form of learning that puts students' learning experience outside the classroom, utilizing the real environment as a learning medium. This approach is supported by the MAA (Mathematical Association of America) which encourages the integration of real activities such as measuring tree heights or exploring geometric patterns in architecture (Marpa & Tolentino, 2023).

According to Anderson (2021), outdoor learning is able to improve students' health, welfare, and environmental awareness. Widiasworo (2017, in Kurniawati, 2021) mentioned the advantages of this method, including: real learning, hands-on experience, and more active and fun learning activities. However, as revealed by Oberle (2021) and Sjöblom (2023), this method also has challenges such as the need for careful planning, difficult classroom control, and dependence on weather and connectivity.

2.3 GPS-Based Mobile Technology-Assisted Math Trail

Imprint Mathematics is a mobile technology-based outdoor learning method with the help of GPS. This application allows teachers to create a math trail that links location points to contextual math problems that students must solve in real time (Cahyono & Ludwig, 2016).

According to Caldeira et al. (2020), the app presents tasks, provides immediate feedback, and allows exploration of real environments to solve problems. The learning process in this method integrates technology (TPACK), pedagogy (outdoor learning), and mathematical content, so that it is in line with the learning needs of the 21st century (Hanik et al., 2022).

2.4 Mathematical Problem-Solving Abilities

Schoenfeld (2013) defines problem-solving as an effort to find a solution to a condition when there is no definite method to achieve it. Polya (1985) proposes four steps to solve problems, namely: understanding the problem, making a plan, implementing the plan, and re-checking. Peranginangina & Edy (2017) added that this ability can be observed through a systematic and logically-based search for answers.

2.5 Mathematical Communication Abilities

Mathematical communication skills refer to the ability to convey mathematical ideas both orally and in writing (Rohid, 2019; Hodiyanto, 2017). According to Tong (2021), the indicators include drawing mathematical ideas, writing ideas, using mathematical language and

symbols, and explaining solutions in writing. Difficulties in mathematical communication are usually caused by a lack of mathematical vocabulary and confidence (Jones & Edwards, 2016).

3. Proposed Method

The research method used in this study is a quasi-experiment with the Nonequivalent Control Group Design. This design was chosen because the researcher did not have complete control over the assignment of subjects into experimental and control groups, but instead used existing classes in schools. The research was carried out at SMP Negeri 1 Malinau Kota, North Kalimantan, by involving two class IX as research subjects consisting of 30 students each. One class was used as an experimental group that received the treatment of Outdoor Learning Math learning using Mathematics Footprint assisted by GPS-based mobile technology, while the other class became a control group that received indoor learning using LKPD (student worksheet) which was also assisted by GPS-based mobile technology but without outdoor activities.

This study aims to describe the influence of technology-based outdoor learning methods on two important skills in mathematics, namely problem-solving skills and students' mathematical communication skills. The free variable in this study was the application of *Outdoor Learning Math* learning using *Mathematics Footprint* assisted by GPS-based mobile technology, while the bound variables were problem-solving ability and mathematical communication ability. Problem-solving skills are defined as students' ability to solve mathematical problems through a series of systematic steps according to the Polya model, namely understanding problems, making plans, executing plans, and re-examining solutions. Meanwhile, the mathematical communication skills referred to in this study are the ability of students to convey mathematical ideas in writing, including the use of symbols, notation, and visual representations in explaining problem solving.

The data collection instruments used in this study consisted of a description test designed to measure the two mathematical abilities as well as an observation sheet on the implementation of learning. Tests of mathematical problem-solving and communication skills have been compiled based on relevant indicators and tested for validity and reliability before use. The validity of the instrument was tested through expert judgment and the calculation of the validity coefficient, while the reliability was tested using the Alpha Cronbach formula. The observation sheet is used to assess whether the implementation of *Outdoor Learning Math* learning is in accordance with the plan and design principles of technology-assisted outdoor learning.

In data analysis, the researcher first conducts analysis prerequisite tests such as normality and homogeneity tests for both pretest and posttest data to ensure that the data is eligible for parametric analysis. Then, to test the simultaneous effect of learning on two abilities at once, Hotelling's T^2 multivariate analysis was used. Meanwhile, to see the effect separately on each ability, a two-party t-test and multivariate variant analysis (MANOVA) were performed. With this approach, researchers can get a complete picture of the effectiveness of the application of outdoor learning based on mobile technology on improving students' mathematical competence.

4. Results and Discussion

4.1. Research Results

Table 1. Problem-Solving Capability Analysis

Statistics	Treatment Class		Control Class	
	Pretest	Post-test	Pretest	Post-test
Minimum	0,0	3,0	0,0	0,0
Maximum	4,0	9,0	4,0	8,0
Mean	1,367	6,567	1,400	5,133
Std.Deviation	1,2994	1,5687	1,3025	2,08
N Valid	30	30	30	30

This study shows that the application of *Outdoor Learning Math* using *Mathematics Footprint* assisted by GPS-based mobile technology has a significant influence on improving students'

mathematical problem-solving and communication skills. Based on data from Table 1, there was an increase in the average score in problem-solving skills in the treatment class, from a pretest of 1,367 to a post-test of 6,567. Meanwhile, the control class only increased from 1,400 to 5,133, which meant that the treatment class saw a larger increase of 5.2 points compared to the control class increase of only 3,733 points

Table 2. Results of the Problem Solving Ability t-test

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Itself.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Post_KPM	Equal variances assumed	,519	,474	3,013	58	,004	1,4333	,4757	,4812	2,3855

The results of the t-test on problem-solving ability presented in Table 2. showed a *calculated t-value* of 3.013 and *a p-value* (Sig. 2-tailed) of 0.004 < 0.05, which means that there was a significant difference between the control class and the treatment class. The difference in average score of 1.4333 with a 95% confidence interval between 0.4812 to 2.3855 indicates that students who learn with an outdoor approach have better problem-solving skills.

Table 3. Mathematical Communication Ability Analysis

Statistics	Treatment Class		Control Class	
	Pretest	Post-test	Pretest	Post-test
Minimum	0,0	0,8	0,0	0,0
Maximum	2,3	9,2	3,1	9,2
Mean	0,410	5,69	0,237	4,353
Std.Deviation	0,7712	2,1908	0,6195	2,7129
N Valid	30	30	30	30

The same thing is also seen in mathematical communication skills. Based on Table 3, there was an average increase from pretest to post-test in the treatment class of 5.28 points, while in the control class it was only 4.116 points. Table 3. Reinforcing this by showing that *the T counts* as 2.100 and *the P-value* as 0.040 < 0.05, which means that there is a significant difference between the two classes. The average difference of 1.3367 shows the advantages of the outdoor learning approach in developing students' communication skills.

Table 4. Results of the t-test Post-test Mathematical Communication Ability

Independent Samples Test									
	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Itself.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper

Post_ KKTP	Equal variances assumed	,682	,412	2,100	58	,040	1,3367	,6366	,0623	2,6110

However, in the test of the minimum value standard (KKTP 70), the results *of the one-sample t-test* on problem-solving ability showed an average value of 65.67 (t = -1.513, p = 0.141), and in mathematical communication ability showed an average value of 56.93 (t = -3.267, p = 0.003). These two average scores do not reach the school's standard scores, so statistically, the *Outdoor Learning Math* approach is not strong enough to be said to meet the minimum grade standards set by the school.

Overall, the results of this study show that although *Outdoor Learning Math* with GPS technology provides a significant improvement compared to conventional learning based on LKPD, its effectiveness still needs to be improved in order to fully meet the minimum learning completeness criteria (KKTP). Reinforcement strategies may be needed, such as adjusting track travel time, material variations, and students' habituation to outdoor learning models.

4.2. Discussion

The discussion of the results of the study shows that the application *of Outdoor Learning Math* using mathematical traces assisted by GPS-based mobile technology has a meaningful influence on students' problem-solving and mathematical communication skills when viewed simultaneously. Based on the results of Hotelling's T^2 multivariate statistical test, it was found that there was a significant difference between the experimental group and the control group in terms of the ability to solve problems and communicate mathematically, with a significance value of 0.000 < 0.05. These results show that the use of GPS-based mobile technology in outdoor learning can increase students' involvement in solving mathematical problems and communicate their ideas better than conventional indoor LKPD-based learning.

However, when analyzed separately using *an independent sample t-test*, different results were found. For problem-solving ability, the average post-test of experimental class students was 6,567, higher than the control class of 5,133. Significance values of 0.004 < 0.05 indicate that the difference is statistically significant. This means that an outdoor activity-based learning approach is able to encourage students to understand problems in a real context, plan solution steps, perform calculations, and examine the results more effectively. This is in line with the opinion of Schoenfeld (2013) who emphasizes that problem solving requires heuristic strategies, self-monitoring, and a belief system in one's own abilities.

On the other hand, the results of the t-test for mathematical communication ability also showed significant differences between the experimental and control groups, with significance values of 0.040 < 0.05. This shows that students who learn with the *Outdoor Learning Math* approach tend to be better able to express their mathematical ideas in written form, either through pictures, mathematical notation, or narrative descriptions. This finding is reinforced by the research of Fajriah & Soraya (2017) who reported that outdoor learning with concrete media can improve students' mathematical communication activities and skills. Activities such as direct observation, physical measurement, and modeling of real objects help students understand context and convey it clearly in mathematical language.

However, there is an important note from the results of the one sample t-test which shows that the average post-test results of students in the experimental class are still below the criteria for completeness of learning objectives (KKTP) set by the school, which is 70. This indicates that although this method provides statistically significant improvements, it is not yet fully able to meet the overall standards of student learning achievement. Possible causes include limited time for outdoor learning, student fatigue due to walking long distances in one learning session, and technical obstacles such as dependence on a stable internet network to access GPS-based applications.

In addition, several external factors such as students' physical and mental readiness, learning motivation, and adaptation to new learning situations outside the classroom also affect the effectiveness of the application of this method. As revealed by Oberle (2021) and Sjöblom (2023), outdoor education demands careful planning and can pose challenges such as weather disturbances, more difficult surveillance, and security risks. Therefore, to increase the effectiveness of this method, it is recommended that teachers design shorter but dense

learning paths, provide adequate measuring tools, and prepare students physically and mentally before the activity begins.

Considering the overall findings, it can be concluded that the *Outdoor Learning Math* approach using GPS-based mobile technology-assisted math traces has strong potential in improving students' mathematical problem-solving and communication skills. However, the success of its implementation is highly dependent on the readiness of facilities, geographical conditions, and careful learning planning. This research supports previous literature suggesting the integration of technology and real activity-based learning to address challenges in 21st-century mathematics teaching.

6. Conclusions

Outdoor Learning Math uses a GPS-based mobile technology-assisted mathematics trail compared to indoor learning using LKPD, a mobile technology-assisted mathematics trail on students' problem-solving abilities. Outdoor Learning Math using GPS-based mobile technology-assisted mathematics traces is influential compared to indoor learning using LKPD, mobile technology-assisted mathematics traces on students' mathematical communication skills. Outdoor Learning Math using GPS-based mobile technology-assisted math traces has no effect on students' problem-solving abilities. Outdoor Learning Math using GPS-based mobile technology-assisted math traces has no effect on students' mathematical communication skills.

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