Jurnal Pendidikan Matematika
https://doi.org/10.22342/jpm.v18i3.pp485-498

Learning Numeracy around School Environment Supported by Mobile Math Trails using Problem-Based Learning Model

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Abstract

This study explores how integrating Mobile Math Trails within the Problem-Based Learning (PBL) model can effectively support numeracy learning. This research was conducted using a design research method with an exploratory approach focused on the design experiment stage. The study involved eighth-grade students from SMP N 39 Semarang. Data was collected through observation, questionnaires, portfolios of students' work, and interviews. The findings show that Mobile Math Trails-supported learning using PBL model can be an alternative numeracy reinforcement learning. The tasks design students explore around the school environment refers to numeracy indicators with specific content, context, and cognitive levels. The features embedded within the Mobile Math Trails application assist students in the problem-solving process. The tasks designed within the application foster a direct link between mathematical concepts and real-world scenarios within the school environment, thereby necessitating students' reasoning skills. Active student involvement is crucial in this learning, as collaboration among peers is essential for generating optimal learning experiences. Moreover, the learning steps outlined in the research necessitate students' physical engagement. Future studies could explore the application of numeracy reinforcement learning facilitated by Mobile Math Trails in diverse environments.

Keywords: Mobile Math Trails, Numeracy Skill, Problem-Based Learning, School Environment, Design Research

How to Cite: Nurin, N. S., Junaedi, I., & Cahyono, A. N. (2024). Learning numeracy around school environment supported by mobile math trails using problem-based learning model. *Jurnal Pendidikan Matematika*, *18*(3), 485-498. https://doi.org/10.22342/jpm.v18i3.pp485-498

INTRODUCTION

Numeracy, a fundamental skill assessed in the Minimum Competency Assessment (AKM), extends beyond mere problem-solving in the academic realm (Indonesia. Ministry of Education and Culture, 2020). Its significance for students transcends the classroom, aiding their preparation for professional opportunities and facilitating sound financial management. Moreover, a strong numeracy foundation equips individuals to tackle mathematical challenges encountered in everyday life effectively (Støren et al., 2018). Numeracy skills empower students to effectively tackle mathematical challenges within their surroundings. Proficiency in numeracy encompasses adeptness in data assumption, interpretation, reasoning, problem-solving in real-world contexts, and articulating mathematical concepts (Jain & Rogers, 2019).

However, prevailing conditions indicate that numeracy proficiency among Indonesian students remains relatively low (Setiyani et al., 2024). One contributing factor is the insufficient practice of numeracy-related questions (Purnomo et al, 2022). Consequently, there is a pressing need for solutions that foster numeracy skill development. The contemporary trend of technological advancement permeates various facets of life, including education (Sholikhah & Cahyono, 2021).

Received March 18, 2024; Revised August 24, 2024; Accepted August 31, 2024

Technology has a pedagogical function that can help address the poor performance of mathematics education (Perienen, 2019). Extensive research has been conducted on incorporating technology into mathematics education, with one notable example being the implementation of Math Trails for outdoor learning. Previous studies also have discussed Math Trails which can support various student skills. For example, Math Trails can support mathematical modelling skills (Cahyono et al., 2020), critical thinking skills (Buchori & Puspitasari, 2023), spatial skills (Laššová & Rumanová, 2023), and mathematical literacy skills (Hakim et al., 2022). The skill that is closest to numeracy is mathematical literacy, as mentioned in Geiger et al. (2015) which states that numeracy is also known internationally by other terms such as mathematical literacy. However, Hakim and colleagues (2022) does not integrate Math Trails with the PBL model. Cahyono & Ludwig (2018) explored the potential of utilizing Mobile Math Trails digital technology via MathCityMap, revealing improved student performance and facilitating meaningful learning experiences.

This study will employ the MathCityMap application as a learning tool. Math Trails have been found to cultivate a positive attitude and increase student engagement in learning (Barbosa et al., 2022), as they present math problems within real-world contexts (Barbosa et al., 2022; Jablonski et al., 2018). Hakim and colleagues (2022) suggest that numeracy indicators can be effectively incorporated into task design within Math Trails. The numeracy indicators employed in this study consist of: (1) using various numerical symbols and concepts to solve problems across diverse daily-life contexts, (2) analyzing information presented in various formats such as graphs, tables, charts, and diagrams, and (3) interpreting the analysis outcomes to predict and make informed decisions (Begum et al., 2021; Indonesia. Ministry of Education and Culture, 2017).

In relation to the implementation of the learning model in this study, research conducted by Civil and Hunter (2015) demonstrated that by negotiating classroom norms, teachers can create mathematics classroom where students engage in problem-solving activities tied to real-life problems, helping to develop their numeracy skills. Moreover, prior study found that incorporating problem-based learning through technology, such as experience-driven game, helped to engage children in reflecting on everyday mathematical experiences, thereby enhancing their numeracy skills (Ke, 2014). However, as of now, there has been little research on the integration of PBL with Math Trails to support students’ numeracy skills. Therefore, the novelty of this article lies in the integration of Math Trails with the PBL model to enhance students' numeracy skills. Problem-based learning as a targeted model for improving numeracy skills 9 (Civil & Hunter, 2015).

According to Botty and colleagues (2016) the syntax of PBL involves orienting students to problems, organizing learning activities, guiding individual and group investigations, developing and presenting work, and analyzing and evaluating the problem-solving process. Importantly, the application of PBL extends beyond classroom settings. The integration of the PBL model in outdoor learning allows PBL to be carried out outside the classroom by considering supporting aspects of learning outside the classroom. Consequently, using Mobile Math Trails can be optimized within the context of numeracy learning through the PBL model. This study aims to explore how numeracy learning can be effectively supported by integrating Mobile Math Trails within the PBL model.

METHODS

This study employs an exploratory approach involving 28 students of eighth grade from SMP N 39 Semarang. This study employs a design research approach that includes three stages: (1) preliminary design, (2) design experiments, and (3) retrospective analysis (Bakker, 2018), specifically focusing on the design experiment stage. The research consists of two phases: initial trial experiments conducted on a small scale (pilot experiment) and larger-scale experiments (teaching experiment). Researchers closely accompany students and observe their activities throughout the process. Data collection methods include participatory observations, questionnaires, student portfolios, and interviews. Data analysis techniques include quantitative and qualitative analysis. Quantitative data analysis includes normality test and paired sample t-test from the results of pre-test and post-test data which were analysed using the Statistical Package for Social Sciences (SPSS) software to find out whether there were differences in numeracy skills between before and after the intervention. Qualitative data analysis with data triangulation to see the attachment obtained from data sources in the form of student portfolios on worksheets and observation sheets during learning. The instruments used include pre-test and post-test questions on numeracy skills, practicality questionnaires, and observation and interview sheets.

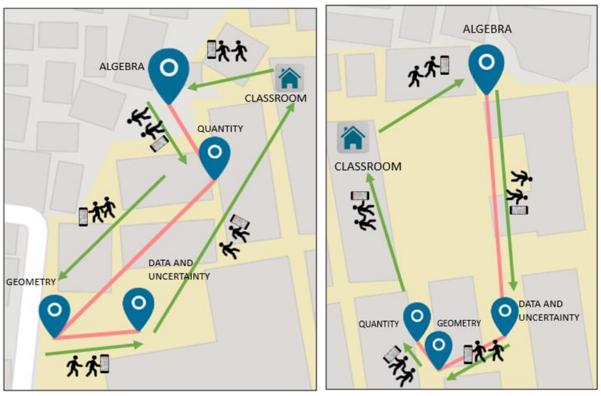
RESULTS AND DISCUSSION

In this study, the concept of Math Trails, facilitated by the MathCityMap digital application, is specifically referred to as "Mobile Math Trails" (Barbosa & Vale, 2023; Cahyono & Ludwig, 2018; Nugraha et al., 2023). Initial observations focused on identifying objects within the school environment suitable for reinforcing numeracy skills. These objects include school stairs, Engklek games area, fishpond, library shoe rack, park bench, wall magazine, composting banner, and basketball court (Figure 1). Outdoor Mathematics Learning entails utilizing the surrounding environment as a resource for learning mathematics and addressing real-world problems (Pambudi et al., 2022). Numeracy is closely related to solving mathematical problems (the essence of mathematics learning) which is not limited to solving routine mathematical problems but finding solutions to contextual problems faced every day where reasoning is absolutely necessary (Dalim et al., 2023; Firdaus et al., 2023). The numeracy indicators utilized in this study include (1) using various numerical symbols and concepts to solve problems across diverse daily-life contexts, (2) analyzing information presented in various formats such as graphs, tables, charts, and diagrams, and (3) interpreting the analysis outcomes to predict and make informed decisions (Begum et al., 2021; Indonesia. Ministry of Education and Culture, 2017).

These three indicators serve as a basis for determining learning activities, primarily focusing on designing outdoor tasks. The selection and development of learning tasks, integral to student engagement in the classroom, are crucial aspects of lesson planning (König et al., 2021). These tasks are designed with varying cognitive levels in mind, ranging from understanding and application to reasoning. Intellectually challenging tasks may encompass different difficulty levels across various dimensions (Kang, 2017). The designed tasks are subsequently uploaded to the www.mathcitymap.eu portal. These tasks, presented in two distinct trails on MathCityMap, have undergone validation by experts (Nurin et al., 2023). The validation results require several revisions such as adjustments to learning objectives, content and question format. The tasks have added material, changed locations, and improved question formats to increase learning effectiveness and context relevance. Some questions were changed from complex multiple choice to fill-in-the-blank type, and certain material was changed to better fit the current curriculum. Each trail incorporates tasks covering Quantity, Geometry, Data and Uncertainties, and Algebra content (Figure 1).

Figure 1. Tasks design

Task contexts encompass personal, socio-cultural, and scientific dimensions. Students engage in group activities with 4-5 members per group, each utilizing a smartphone to access the trails through the MathCityMap app. Active student involvement is essential as collaboration among peers fosters optimal learning experiences and outcomes. Collaborative learning is implemented based on the premise that the learning process is inherently social, with each group member actively participating in discussions to collectively accomplish tasks assigned by the teacher (Pambudi et al., 2022).



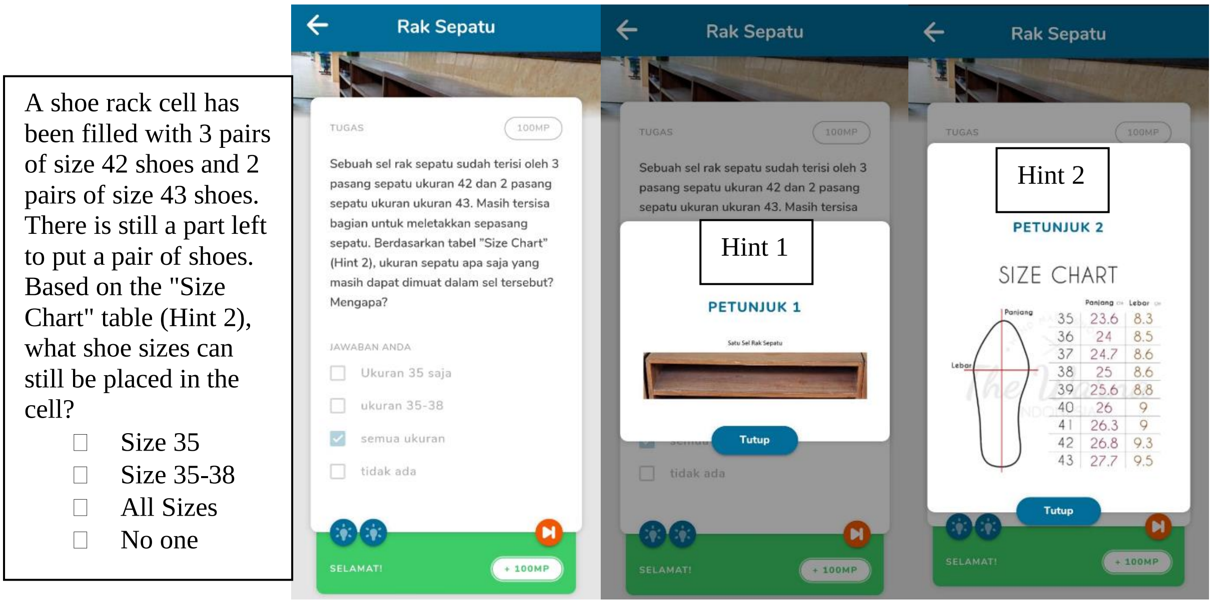
(a) (b)

Figure 2. Student activity illustration : (a) Trail 1; (b) Trail 2

The activities conducted in this study also emphasize students' physical engagement to prevent boredom and promote active learning. The task design was divided into 2 different trails (Figure 2), each trail has the same type of content with a different context. The distance between tasks was also a consideration in determining trail 1 and trail 2 for time efficiency. Trail 1 was done at the first meeting, trail 2 was done at the second meeting. The reason for creating these 2 trails is to increase the variety of tasks and students can experience a variety of mathematical contexts and challenges, which helps deepen their understanding. Learning through Mobile Math Trails adheres to the principles of active learning, enhancing the meaningfulness of learning experiences for students by directly involving them in the problem-solving process. This approach aids students in comprehending the practical applications and utility of mathematics (Barbosa & Vale, 2023). The study comprises two phases: a pilot experiment and a teaching experiment. During the pilot experiment, researchers conducted small-scale trials with groups to obtain initial evaluations of the designed tasks before proceeding to the second stage, the teaching experiment. Teaching experiments were carried out on a larger scale, focusing on implementing the PBL model in numeracy learning with Mobile Math Trails.

Pilot Experiment

The findings were derived from the analysis of student work and testimonials obtained during participation in outdoor learning activities. The analysis revealed that one of the factors contributing to students' inaccuracies in answering questions was their difficulty in grasping the contextual relevance of the questions. Following post-lesson interviews, students suggested the incorporation of hints as a supportive feature. Hints, which provide gradual assistance, have been shown to positively impact performance and learning outcomes (Jablonski et al., 2018). These hints may take the form of images, text, or videos, serving as aids for students to successfully complete assignments (Barlovits et al., 2022). An example task within this context is Task 4, "Rak Sepatu (Shoe Rack)" (Figure 3).



(a) (b) (c)

Figure 3. Task 4: (a) Task description; (b) Hint 1; (c) Hint 2

This task involves problem-solving aligned with indicators related to analyzing information presented in tabular forms and interpreting the outcomes to make predictions and decisions. The objective of this task is for students to determine which shoe sizes can fit into the remaining space on the shoe rack. The anticipated problem-solving process entails students understanding the task details, measuring the length of one cell of the shoe rack, determining the length of the section filled with shoes by referencing the 'Size Chart' table, and then inferring the length of the remaining unfilled section to arrive at the answer. Initially, the task lacked an explanation or description of one cell of the shoe rack. Consequently, students mistakenly measured the height of the shoe rack instead of the width of the shelf (see Figure 4). To address this issue, a hint was incorporated, providing clarification on the meaning of one cell of the shoe rack in Hint 1.

Figure 4. Students Activity in Task 4

Determining the appropriate distance for the answer interval in interval-type questions emerges as a significant finding. Discrepancies in measurements commonly arise in geometric and measurement domains, necessitating the establishment of a tolerance limit for answers deemed acceptable by the system. Particularly for modelling tasks, intervals prove highly relevant as they mitigate minor variations in solutions, such as measurement discrepancies (Jablonski et al., 2018). In Task 8, the solution format prior to revision was presented as an exact value (see Figure 5).

Figure 5. Task 8 solution format before revision

Students' responses deviated from the expected answer (Figure 6), which should be 75.25 cm³, with students providing 82 cm³ instead. Analysis from Figure 5 indicates that the disparity in answers stems from discrepancies in the length and width measurements. While the correct values should be length = 25 cm and width = 19 cm, students erroneously recorded length = 26 cm and width = 20 cm. Despite this, the calculations performed by students were accurate. Therefore, it is imperative to revise the answer format to accommodate student responses that are close to the expected results but contain tolerable measurement errors.

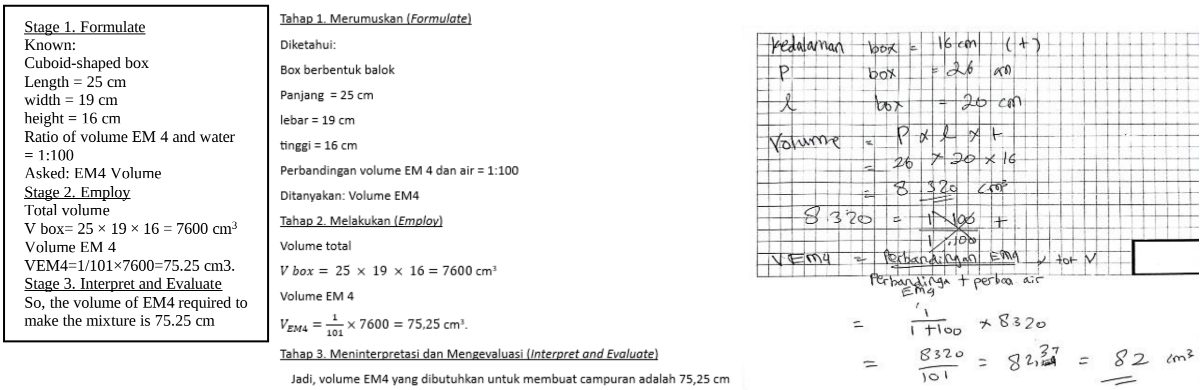


Figure 6. Comparison between Expected Solutions and Student Answers

The answer interval follows the format of the system, where green is for the correct solution, and the orange interval is for the wrong, but acceptable solution (Jablonski et al., 2018). Table 1 provides the calculated solution format with an error limit of ±0,5 for green solutions and ±1 for orange solutions.

Table 1. Calculation of task 8 solution interval

	Correct Answer	Minimum (orange)	Minimum (green)	Maximum (green)	Maximum (orange)
Length	25	24	24,5	25,5	26
Width	19	18	18,5	19,5	20
Height	16	15	15,5	16,5	17
Vol EM4	75,25	64,16	69,56	81,23	87,52

After obtaining the results of the interval calculation, then inputted into the interval in the MathCityMap application (Figure 7). Another noteworthy finding at this stage pertains to the optimal number of group members. Determining the group size is crucial as it impacts time efficiency, task allocation, and the skill of each member to contribute effectively. Groups are divided based on students' mathematical skills, reviewed based on mathematics scores in the previous semester. Each group has 1 student as the leader with good mathematical skills. Students have indicated that groups consisting of four members are ideal, as this facilitates an even distribution of tasks. When forming groups, it is essential to consider students' characteristics, typically based on: (a) Students' skills or intelligence, including understanding, future planning skills, and foresight; (b) Variances in students' learning interests; (c) Differences in student learning objectives (Maqtary et al., 2019).

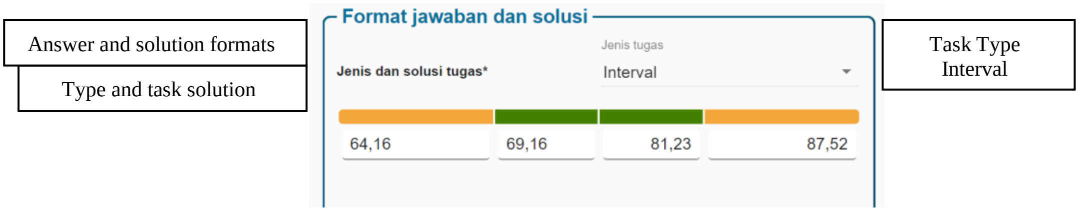


Figure 7. Task 8 solution format after revision

Teaching Experiment

At the teaching experiment stage, learning activities using Mobile Math Trails in outdoor learning are adjusted to the syntax of the PBL model. The outdoor learning stage includes: (1) briefing phase, (2) guiding students out of class, (3) learning activities in teams, (4) evaluation, and (5) appreciation (Kelly et al., 2022). However, in this study, these stages are summarized into three stages, that include preparation (briefing phase and guiding students out of class), implementation (learning activities in teams), and evaluation (evaluation and appreciation). Table 2 describes the relationship between the stages in outdoor learning and the PBL model then integrated with learning activities with Mobile Math Trails in this study.

Table 2. Integration of outdoor learning methods, PBL Models, and Mobile Math Trails

Outdoor Learning Steps	PBL Syntax	Mobile Math Trails Activity Steps
Step 1. Preparation	1. Orienting students to the problems	• Students are informed about learning objectives and instructions for using MathCityMap Application. • Students prepare tools and materials needed during learning activities.
Step 2. Implementation	2. Organizing students to learn 3. Guiding individual and group investigations	• Students observe the route given at MathCItyMap. • Students explore objects on the route created then make observations and collect data. • Students process the data obtained by discussing in groups.
Step 3. Evaluation	4. Developing and presenting work 5. Analyzing and evaluating the problem-solving process.	• All students return to class, then each group presents the results of the discussion of the activities that have been carried out.

During the problem orientation phase, one group encountered difficulty accessing the code due to unreliable internet connectivity. As MathCityMap operates as a mobile application reliant on internet access (Ludwig & Jesberg, 2015), it's imperative that the mobile devices intended for use are prepared beforehand to ensure efficient learning durations.

In the organizing phase, researchers elucidate the travel routes for each group and allocate an ideal timeframe for each task point, while also distributing worksheets. The student worksheets utilized in this study are automated and downloadable through the MathCityMap application. During the guiding phase of individual and group investigations, students proceed to their designated assignment points. This research leverages digital platforms, enabling real-time monitoring of students' progress in activities (Taranto et al., 2021). Additionally, the use of digital platforms allows for tracking of individual scores, fostering healthy competition among students alongside collaborative group work (Chen et al., 2020; Maryanti et al., 2020). While the chat feature within the digital platform exists, its functionality was limited in this study as researchers prioritized on-site conditions. However, it holds potential for effective use in distance learning scenarios. Larmann et al. (2022) explored the use of MathCityMap in distance learning (MCM@home), where the chat feature served as a means for students to pose questions to teachers. During the phase of developing and presenting work, students record their findings on provided worksheets for subsequent presentation in class.

An obstacle encountered in this study was the discrepancy between the planned duration of outdoor learning and the practical implementation in the field. Research by Ayotte-Beaudet et al. (2023) regarding teachers' perceptions of classroom learning in Canada suggests that outdoor learning sessions for levels 7-11 (equivalent to junior and senior high school levels in Indonesia) typically last between 61-120 minutes. However, in this study, the duration of outdoor learning was limited to 80 minutes for the entire learning sequence, including preparation and discussion of questions. This limitation arose from the school's scheduling constraints, as only 2 hours of lessons were allotted per meeting. Consequently, the phase of analyzing and evaluating the problem-solving process had to be conducted over multiple meetings. On average, each group was only able to complete 3 out of 4 questions. Therefore, it would be more effective to extend the duration of outdoor learning to 3 hours (120 minutes) per session, enabling all phases of PBL to be completed within a single meeting.

Following the intervention, test results utilizing questions based on numeracy indicators revealed a significant difference ($p < 0.05$) in students' numeracy skills before and after the intervention. The average score after the intervention (81.96) surpassed that before the intervention (48.29). Subsequently, students were administered questionnaires pertaining to the learning principles of numeracy reinforcement. The majority of students (87%) agreed that this learning approach enhances their skill to use mathematics to solve real-life problems, while 86% agreed that it enhances their analytical skills to solve problems. Additionally, 83% of students agreed that this learning method aids in predicting outcomes and making decisions. These findings suggest that the learning approach employed in this study effectively supports numeracy reinforcement learning.

This study introduces the innovative integration of Mobile Math Trails through the digital application MathCityMap by utilizing the school environment to strengthen numeracy skills. Important findings in this study that become the novelty in this research include challenges in contextual relevance that were overcome with the help of instructions in the MathCityMap application, the importance of tolerance in answers to accommodate measurement variations, the successful integration of Mobile Math Trails with the PBL model, and the effectiveness study group consisting of four students. Additionally, a longer duration of learning in the school environment is proposed to complete the entire PBL phase, which is proven to significantly improve students' numeracy skills and strengthen their skill to apply mathematics in real life.

CONCLUSION

The findings underscore that Mobile Math Trails-supported learning, coupled with the PBL model, offers a novel mathematical learning experience beyond the classroom. The features embedded within the Mobile Math Trails application assist students in the problem-solving process. The tasks designed within the application foster a direct link between mathematical concepts and real-world scenarios within the school environment, thereby necessitating students' reasoning skills. This approach aligns with the principles of numeracy, making this research a valuable reference for numeracy reinforcement learning. Active student involvement is crucial in this learning approach, as collaboration among peers is essential for generating optimal outcomes and learning experiences.

Moreover, the learning steps outlined in the research necessitate students' physical engagement. Future studies could explore the application of numeracy reinforcement learning facilitated by Mobile Math Trails in diverse environments.

ACKNOWLEDGMENTS

We would like to express gratitude to LPPM UNNES for providing a research grant through DIPA UNNES with Number: 633.12.4/UN37/PPK.10/2023. Our gratitude also goes out to our colleagues, as well as the students and teachers of SMP N 39 Semarang who participated in this research.

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