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Mathematical Modelling Ability in Outdoor Learning with Mobile Math Trails

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Abstract

The aim of this study is to describe how outdoor learning with mobile math trails can support students' mathematical modelling ability. The method used is design research with three phases, namely preparation and design, teaching experiment, and retrospective analysis. This study was conducted at junior high school involving 32 students. The Hypothetical Learning Trajectory (HLT) was designed and learning activities that include several math trails tasks were created, then students run the activity. Data were collected by observation, interviews, tests, and worksheets. The findings indicate that the learning activity that has been implemented can support students' mathematical modelling ability. The learning activity can provide opportunities for students to engage in meaningful mathematical modelling activities in accordance with mathematical modelling indicators. The study identified a link between HLT as learning design and mathematical modelling activities in learning process. In addition, it was found that students' mathematical modelling ability had improved.

Keywords: mathematical modelling, outdoor learning, mobile math trail, design research.

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INTRODUCTION

The important goal of teaching mathematics is to shape and develop students' abilities in applying their mathematical knowledge to solve problems in everyday life (Tong et al., 2019). This goal is in line with the mathematics framework of the PISA (Program for International Student Assessment) test, where the test describes an individual's capacity to reason mathematically and to use concepts, procedures, facts, and mathematical tools to describe, explain, and predict phenomena or problems in the real world (OECD, 2019). PISA test results organized by the Organization for Economic Cooperation and Development (OECD) in 2018 show that in the field of mathematics, Indonesia ranks 70 out of 77 countries with an average score of 379, far below the international average of 489. Indonesia's average score has decreased compared to the previous PISA test in 2015. These results indicate that students in Indonesia have difficulty solving PISA test questions related to mathematical literacy.

Mathematical literacy is an individual's capacity to formulate, use, and interpret mathematics in a variety of contexts (OECD, 2017). Mathematical literacy can involve transforming real-world problems into mathematical forms (which can include structuring, conceptualizing, making assumptions, and/or formulating models), as well as interpreting and evaluating mathematical results or models related to real-world problems (OECD, 2019). In other words, mathematical modeling activities are the main process in mathematical literacy, where mathematical literacy is related to the ability to apply mathematics to everyday problems (Santi, 2017). So, it can be indicated that the mathematical modelling ability of Indonesian students is still low.

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According to Dawn (2018), mathematical modelling is the process of formulating and improving mathematical models to represent and solve real-world problems. Drijvers et al. (2019) define mathematical modelling as a process of translating a problem situation into mathematical terms and vice versa. Mathematical modelling can be defined as the process of representing real-world problems in mathematical terms to understand and find solutions. Mathematical modeling ability are very important for students to have. Mathematical modeling can clarify the relationship between mathematical concepts and daily experiences (Orey & Rosa, 2018).

Facts in the field show that students have difficulty representing real problems in mathematical models (Pambudi et al., 2021). In line with that, the results of research conducted by Khusna & Ulfah (2021) show that the ability of students to make mathematical modeling is still largely lacking. Learning mathematics in class does not explore students' mathematical literacy skills but only transfers knowledge (Wardono & Mariani, 2018). Students should be given the opportunity to face real-world situations that are relevant to everyday life (Cahyono & Ludwig, 2018). Outdoor learning strategy is suitable to be applied so that students are familiar with real objects in learning mathematics (Cahyono & Ludwig, 2019), and can apply mathematics directly in real life (Ahsan et al., 2020). This learning strategy is also in accordance with constructivism learning theory. The main idea of constructivism is how to provide opportunities for students to understand what they have learned by applying and practicing it in their daily lives (Suparlan, 2019). One technique that is suitable for implementing outdoor learning in mathematics education is the math trails (Gurjanow & Ludwig, 2017).

A math trails is a series of tasks along a pre-planned route, consisting of a series of stopping points where student complete math tasks in their surroundings (Barbosa & Vale, 2020; Cahyono & Ludwig, 2017). Authentic problems must be part of mathematics learning in schools and math trails can provide them (Jablonski & Ludwig, 2020). Therefore, students can view their environment from a mathematical perspective and find mathematical concepts in the environment (Cahyono & Ludwig, 2018; Ismaya et al., 2018). Furthermore, students can apply their mathematical skills in various situations which leads to deeper and contextual mathematical knowledge (Barlovits & Ludwig, 2020). Problems on the math trails can be solved by following the mathematical modelling cycle (Cahyono et al., 2020). Although math trails are not new, the use of mobile technology is an innovative approach to support outdoor learning (Cahyono & Ludwig, 2018).

The use of technology can support students to experience the modeling process (Molina-Toro et al., 2019). One idea that combines the concept of a math trails with the use of technology in a modern learning environment is MathCityMap. MathCityMap aims to involve students in learning mathematics on a math trails program that is supported using GPS on mobile technology (Cahyono & Miftahudin, 2018). The Mobile Math Trails program can support students in bridging between real-world situations and mathematical concepts in problem-solving following the mathematical modeling cycle (Cahyono et al., 2020). Thus, the use of the mobile math trails (which in this study is the MathCityMap application) as an outdoor learning medium is expected to make a positive contribution to students' mathematical modelling ability.

The aim of this study is to describe how outdoor learning with mobile math trails can support students' mathematical modelling ability, and to find out how students' mathematical modelling ability are after the implementation of outdoor learning with the mobile math trails.

RESEARCH METHOD

The method used in this study is Design Research. Design Research is a systematic study to design, develop and evaluate educational interventions, such as programs, learning strategies, learning process, teaching materials, and educational systems as solutions to solving complex problems in educational practice, which also aims to advance our knowledge about the characteristics of the interventions (Prahmana, 2017). Design research aims to generate actionable knowledge or theories about learning that can be implemented to achieve some educational goals (Bakker, 2018). There are three phases of Design Research method, namely preparation and design, teaching experiment, and retrospective analysis. This research was carried out at junior high school involving 32 students. Data were collected by observations, tests, worksheets, interviews, and documentations.

RESULTS AND DISCUSSION

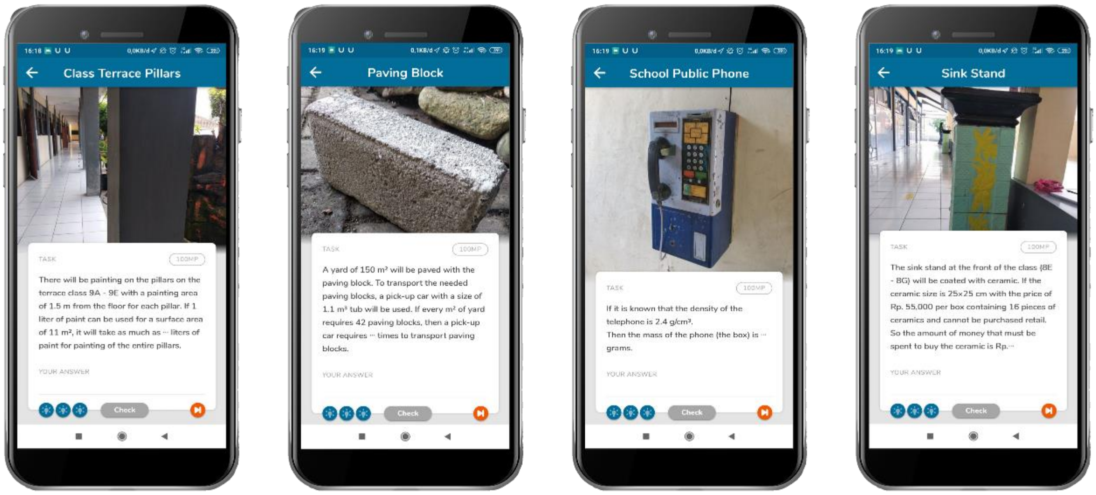
The research results will be presented in 3 phases according to the Design Research phases. To answer research questions and achieve research objectives, the research results that have been obtained will be discussed by focusing on student modelling activities in the learning process and students' mathematical modelling ability after the implementation of outdoor learning with mobile math trails.

Preparation and Design

From the interview, it is known that junior high school uses the 2013 curriculum. The learning process which tends to be passive and does not involve students makes learning activities boring and minimal interaction. The characteristics of students who tend to be passive due to being accustomed to online learning. In addition, it is also known that students have difficulty solving problems in the form of stories or contextual problems. Meanwhile, the media used in learning tend to be passive and only convey material. There is no media that can actively involve in building their knowledge. So, we need the learning activities that can actively involve students in the learning process. In addition, media is needed that can bring students closer to learning resources and deal with contextual problems. Observations were also conducted in the school environment to determine which objects would be used as stopping points on the Mobile Math Trails. The math trails can see in Figure 1.

Figure 1. Math Trails

The HLT was designed based on the results of interviews, observations, discussions with supervisors, and literature studies. Then the author designs learning activities according to HLT in the form of lesson plans and MathCityMap (MCM) tasks. The MCM tasks can see in Figure 2.



(a) (b) (c) (d)

Figure 2. MathCityMap Tasks

At the stopping points (a) Class Terrace Pillars and (d) Sink Stands, contextual problems related to the surface area of Polyhedra was created. Meanwhile, at the stopping point (b) Paving Block and (c) School Public Phone, contextual problems related to the volume of Polyhedra was created. The designed MCM task has been adapted to the MathCityMap task criteria (Jablonski et al., 2018) and indicators of mathematical modelling ability (Kaiser, 2007). The designed MCM tasks has been reviewed by the MathCityMap reviewer.

Teaching Experiment

In the teaching experiment phase, the sequence of activities includes small group trial, pre-test, implementation, and post-test. The data from the small group trial results used as input for revising Table 1. Hypothetical Learning Trajectory (HLT), as well as input from supervisors and teachers. The final HLT can see in Table 1.

Table 1. Hypothetical Learning Trajectory (HLT)

Learning Goal	Learning Activity	Hypothesized Learning Process
Students can solve contextual problems related to surface area and volume of Polyhedra using mathematical modelling cycles.	Students explore contextual problems related to objects in a school environment using the MathCityMap apps. Students can also use the available hints.	Students understand real-world problems contained in the mobile math trails. Students also ask questions to guide understanding, such as the shape of the object, what is known, what is asked.
	Students make observations on objects and collect data through calculations, measurements, literacy, and experiments on objects and the problems.	Students identify what data is needed to solve the problem. The data is used by students to build real-world models and simplify the problems.

	Students process the data obtained and discuss it in groups, to then be presented on the Student Worksheet.	Students use data to create a mathematical model from a real-world model. Students solve mathematical problems in mathematical models using concepts or formulas related to Polyhedra material. Students interpret mathematical results into real-world models or actual situations.
	Students check their answers on the MathCityMap apps. And asked to re-correct their answers if there are errors.	Students validate the solutions that have been found. If it is still wrong, then the student will repeat the mathematical modeling process.
	Each group presents the results of their discussion, and the other groups give their responses.	Students communicate their work to strengthen the concepts they have learned.

After the pre-test, the implementation was carried out on class VIII-A with 32 students at junior high school. The learning process is carried out in accordance with the lesson plan created based on HLT. The time allocation is 3 lesson hours (3×40 Minutes) with the main subject of Polyhedra.

In the preliminary activity, the teacher opens the lesson by greeting and praying with the students. Then proceed with checking the attendance of students, providing motivation and information about the learning activities to be carried out. In the core activity, students are asked to open the MathCityMap application and prepare to explore the school environment to find objects related to contextual problems. Then students are divided into several groups and given directions about what to do during the learning process. Students look happy and enthusiastic when invited out of class. Next, students make observations and collect data through exploration and experimentation following the math trails in the MathCityMap application. When students have difficulty understanding the problem and what to do to solve it, students take advantage of the hints feature which contains stimulus questions.

Figure 3. Students' Activity

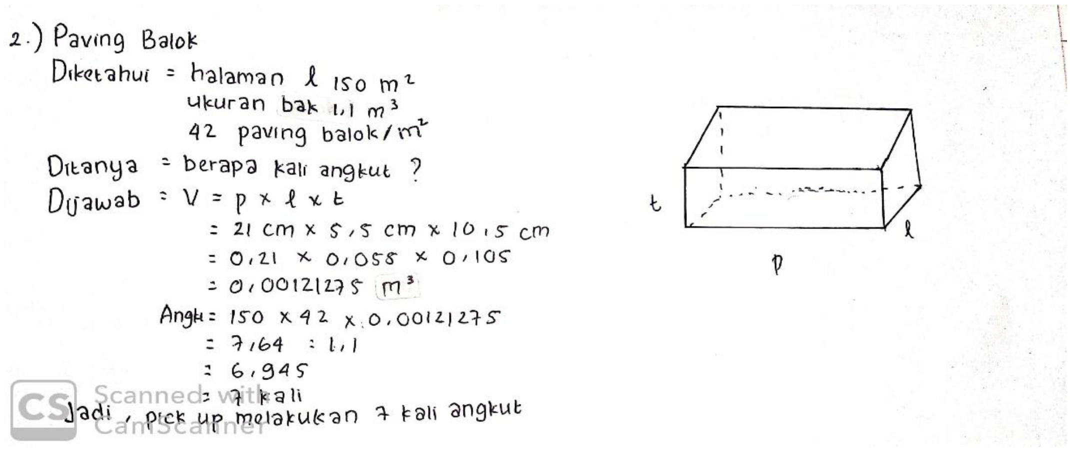

2.) Paving Balok
Diketahui = halaman l 150 m^2
ukuran bak 1,1 m^3
42 paving balok/m^2
Ditanya = berapa kali angkut ?
Dijawab = $V = p \times l \times t$
= 21 cm × 5,5 cm × 10,5 cm
= 0,21 × 0,055 × 0,105
= 0,00121275 m^3
Angk = 150 × 42 × 0,00121275
= 7,64 : 1,1
= 6,945
= 7 kali
Jadi, pick up melakukan 7 kali angkut

Figure 4. Example of Students' Worksheet

After observing the object and collecting data through counting, measuring, literacy, and experimenting with the object and the problems encountered, students then process the data obtained and discuss it in groups, to then be presented on student worksheets. After finding the results, students check their answers on the MathCityMap application. There are some answers that are not correct, so students check and rework the questions. If the answer is correct and MathCityMap gives feedback in the form of points, students look happy and cheer. Next, each group presented the results of their discussion, and the other groups gave their responses. After implementation, post-test of mathematical modelling ability were conducted.

Retrospective Analysis

In this phase, all data obtained from the implementation phase will be analysed. The research focus is to describe how outdoor learning with mobile math trails can support students' mathematical modelling ability and to find out the improvement of students' mathematical modelling ability after the implementation of outdoor learning with the mobile math trails.

Analysis of Students' Mathematical Modelling Activity

The HLT that has been designed before would be compared with the data from the implementation of outdoor learning with mobile math trails. The findings indicate that the learning activity that has been implemented can support students' mathematical modelling abilities. The learning activities can provide opportunities for students to engage in meaningful mathematical modelling activities in accordance with mathematical modelling indicators. The mathematical modeling indicators that refer to Kaiser (2007), namely: 1) students can understand real-world problems and build real-world models (*understanding & simplifying*); 2) students can make a mathematical model of the real-world model (*mathematizing*); 3) students can solve mathematical problems in mathematical models (*working within mathematics*); 4) students can interpret mathematical results into real-world models or actual situations (*interpreting*); 5) students can test the solutions that have been obtained (*validating*). The identification of the relationship between Hypothetical Learning Trajectory (HLT) as learning design and mathematical modelling activities in learning implementation can see in Table 2.

Table 2. Relation Between Students' Modelling Activity and HLT

Students' Modelling Activity	Hypothesized Learning Trajectory (HLT)	Modelling Indicators

Students follow the math trails route to find objects in the school environment using the MathCityMap app. Then students read and understand the problems related to the object. When they encounter difficulties, students take advantage of the hint feature on MathCityMap or ask the teacher.	Students understand real-world problems contained in the mobile math trails. Students also ask questions to guide understanding, such as the shape of the object, what is known, what is asked.	Understanding
Students make observations on objects and collect data through calculations, measurements, literacy, or experiment. Then students write down important things to simplify the problem.	Students identify what data is needed to solve the problem. The data is used to build real-world models and simplify the problems.	Simplifying
Students process the data obtained and discuss it in groups, to then be presented on the Group Worksheet. After writing what is known and what is asked, students make mathematical model of the problem in the form of object illustrations or equation.	Students use data to create a mathematical model from a real-world model.	Mathematizing
Then students use formulas related to Polyhedra that match the problem. Next, students perform calculations to find results.	Students solve the problems in mathematical models using concepts or formulas related to Polyhedral material.	Working within Mathematics
After finding the results, students reread what was asked to then conclude the results into real situations.	Students interpret mathematical results into real-world models or actual situations.	Interpreting
Students check their answers on the MathCityMap app and asked to re-examine their answers if they are not correct.	Students validate the solutions that have been found. If it is still wrong, then the student will repeat the mathematical modeling process.	Validating
Each group presents the results of their discussion, and the other groups give their responses.	Students communicate their work to strengthen the concepts they have learned.	

From the Table 2, it can be seen that the learning process that occurs in the field is in accordance with the designed HLT and includes all indicators of mathematical modelling ability. After opening the lesson, the teacher asks students to leave the classroom to explore the planned math trails. Outdoor learning is more interesting for students and can bridge between the theory in the book and the reality in the field. Barbosa & Vale (2016) state that the use of the surrounding environment as a "classroom" can foster a positive attitude and additional motivation to learn mathematics, thereby enabling students to realize the application of mathematics.

At every stopping point on the math trails, students would be faced with contextual problems in the real world to create meaningful learning. This is in accordance with Cahyono & Ludwig (2018) who state that mathematical activities must provide opportunities for students to experience objects in a meaningful way so that they can understand concepts well, and students must be offered real-world situations. In solve the problems, students do not only count, but also perform physical activities such as observing objects and measuring objects directly. This is in accordance with Otte et al. (2019) who state that outdoor learning is an example of teaching that involves elements such as hands-on learning, varied learning, problem-based learning, and physical activity.

Analysis of Students' Mathematical Modelling Ability

The data from the pre-test and post-test results will be analyzed to find out the improving of students' mathematical modelling ability. The test results data were tested for normality test, paired sample t-test, and N-gain test. The results of pre-test and post-test scores can see in Table 3.

Table 3. Results of Pre-Test and Post-Test

Score	Pre-Test	Post-Test
Average	62.03	76.88
Highest	85	97.5
Lowest	47.5	57.5

Based on the results of the normality test, it was found that the pre-test and post-test data were normally distributed. Then, the paired sample t-test was carried out on the data from the pre-test and post-test results. Based on the results of the paired sample t-test, it was found that there were differences in the mathematical modelling abilities of the experimental class students before and after implementation of Outdoor Learning with Mobile Math Trails. Then the N-gain test was carried out to find out how much the improvement of students' mathematical modelling abilities after implementation.

From the results of the N-gain test, it was found that classically the students' mathematical modelling ability had improved in the medium category. While individually, there are 6 students who had improved in the high category, 15 students had improved in the medium category, 11 students had improved in the low category.

Improvement of students' mathematical modelling ability after the implementation of Outdoor Learning with Mobile Math Trails, it's in line with the results of Pambudi's research (2022) which shows that the Outdoor Learning Method has a positive effect on students' motivation and learning achievement on geometry. Druken & Frazin (2018) states that math trails can support the development of students' mathematical modelling abilities by connecting mathematics with the surrounding environment. Mobile Math Trails program can support students in bridging between real-world situations and mathematical concepts in problem solving following the mathematical modeling cycle (Cahyono et al., 2020).

CONCLUSION

Outdoor learning with mobile math trails can support students' mathematical modelling abilities where the learning activity that has been implemented can provide opportunities for students to engage in meaningful mathematical modelling activities in accordance with mathematical modelling indicators. The designed Hypothetical Learning Trajectory (HLT) are in accordance with student learning activities in the teaching experiment. In addition, it was found that students' mathematical modelling abilities had improved in medium category.

Based on the conclusion, the learning design can be implemented by teachers and the Hypothetical Learning Trajectory (HLT) can be used as a reference for developing other learning tools. In addition, this research is still limited to the modelling ability and polyhedra material. Further studies are essential for project development and implementation in other location with different situations and aspects of study.

DECLARATION

Author Contribution

All authors contribute in the research process, such as collecting the data, analyzing the data, and writing the manuscript. All authors approved the final manuscript.

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Conflict of Interest

The author declares that they have no competing interests.

Ethics Declaration

I as author acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that I have obtained permission from the relevant institutes when collecting data. We support the International Journal on Emerging Mathematics Education (IJEME) in maintaining high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

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