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The integration of Ethno-RME in MatCityMap application to support students' learning of system of linear equations: A case of Mangkujo Math Trail

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Abstract

In the rapidly advancing digital era, mathematics education must integrate various technological applications to support students' development for the 21st century. However, mere technological integration is insufficient; learning must also involve hands-on activities and real-life experiences to equip students with essential skills. Although many current math lessons incorporate technology, they often overlook students' real-life experiences. Hence, there is a need for mathematics learning approaches that combine technology with student activities and relate them to real-life contexts. Ethno-Realistic Mathematics Education (Ethno-RME) is an innovative approach that uses real contexts as a starting point for learning. This approach can be enhanced by the MathCityMap (MCM) application, making learning more interactive and engaging for students. Therefore, this study explores the potential of MCM by integrating content from the Ethno-RME approach. MCM is an emerging technology that facilitates the exploration of outdoor mathematics, providing students with contextual and real-life problems. The authors developed mathematical tasks based on a café or resort in a district in Central Java. Through Educational Design Research (EDR), mathematical tasks were created using artifacts available in the café and incorporated into the MCM application. Students could access the tasks from their mobile devices and track their locations (math trails). The study focused on the system of linear equations derived from geometrical objects found in the café. The results indicated positive impacts, such as improved students' conceptual understanding and mathematics performance. This study provides evidence of the effectiveness of integrating Ethno-RME with digital technology to support students' learning of mathematics. Further research is needed to explore more ethnomathematics activities integrated into MCM that are suitable for students' backgrounds and locations.

Keywords: Ethno-RME, Mangkujo, MathCityMap, Math Trail, Two Variable Linear Equation System

Introduction

In the current digital era, technology is advancing rapidly and impacting various aspects of life, including education (Selwyn, 2012; Hashim, 2018). Teachers face the challenge of developing innovative learning methods that integrate technology across various platforms (Cacheiro-Gonzalez et al., 2019; Decuypere et al., 2021). However, it is essential to ensure that learning does not solely focus on digital aspects but also includes student activities and their real-life contexts (Bray & Tangney, 2016). Integrating technology into learning is crucial for preparing students with relevant skills and a deep understanding of concepts (van Laar et al., 2017). Therefore, to effectively engage students, a learning approach that utilizes technology and is relevant to their lives is necessary.

While technology integration in mathematics has commenced, it frequently remains abstract and formal, failing to engage students in real-world activities (Bray & Tangney, 2017). For effective student engagement, it is essential to adopt a learning approach that incorporates technology and is pertinent to students' everyday lives (Chin et al., 2023; Greener, 2022). By merging technological tools with real-life contexts, educators can foster a more engaging and effective learning environment, enhancing students' conceptual understanding and equipping them for future challenges.

The Ethno-Realistic Mathematics Education (Ethno-RME) approach can be utilized to design innovative learning experiences that engage students in activities related to their real-life contexts (Prahmana, 2022). This approach integrates Ethnomathematics with Realistic Mathematics Education, emphasizing the use of real and culturally relevant contexts as starting points for learning. Ethno-RME focuses on student activities through the discovery of concepts, attention to the mathematizing process, and the promotion of self-modeling and higher-order thinking (Prahmana, 2022; Prahmana et al., 2023).

Ethno-RME incorporates principles such as guided reinvention, progressive mathematizing, didactic phenomenology, and self-development models (Prahmana et al., 2023). It is a flexible approach that can be effectively integrated with technology, such as the MathCityMap (MCM) application, to enhance learning outcomes. By leveraging these principles, Ethno-RME provides a comprehensive framework for creating engaging and contextually relevant mathematics education, thereby fostering a deeper understanding and appreciation of mathematical concepts among students.

The MCM app integrates mathematics with real-life activities through smartphone technology, guiding students to explore mathematical concepts using GPS navigation (Ludwig & Jablonski, 2019). This application directs students to interact with real-world objects, facilitating the exploration of mathematical ideas and enhancing their understanding. The tasks provided by MCM actively engage students in the discovery process, allowing them to delve deeper into mathematical concepts.

Cahyono and Ludwig (2019) stated that MCM offers students valuable opportunities to participate in real-life mathematical activities and explorations. This engagement can significantly increase their interest in learning mathematics and help them derive meaningful insights from their educational experiences. By merging technology with practical exploration, MCM enriches the learning process, making mathematics more engaging and relevant to students' lives.

Previous studies have demonstrated that employing innovative learning approaches and media can enhance students' mathematical skills, motivation, and learning outcomes. For instance, Singh et al. (2024) successfully utilized an augmented reality application to teach trigonometry, creating an engaging learning experience in enhancing spatial skills and conceptual knowledge. Additionally, Tetriyani et al. (2024) developed instructional media using video animation for learning a system two-variable linear equation. Lastly, from a 21st-century learning perspective, Realistic Mathematics Education (RME) has been shown to enhance student engagement through the affordances of mobile technology (Bray & Tangney, 2016).

While significant progress has been made in integrating technology into mathematics education to enhance student motivation—such as employing digital writing boards in lectures (Abu & Kribushi, 2022), virtual reality for geometry learning (Su et al., 2022), and digital technologies in geometry instruction (Sunzuma, 2023)—there is still a notable gap in optimizing student activity and participation throughout the learning process. Research indicates that boosting student engagement and active involvement is essential for maximizing the effectiveness of these technological tools and educational methods (Gopinathan et al., 2022; Greener, 2022). This study, therefore, seeks to design a learning experience for the two-variable linear equation system by integrating the Ethno-Realistic Mathematics Education (Ethno-RME) approach with the MathCityMap (MCM) application.

The objective of this study is to deliver innovative learning experiences that incorporate technology, relate to students' real-life contexts, and promote active student participation. This approach aims to serve as a model for educators and researchers in developing technology-based mathematics instruction while preserving the practical relevance of mathematics. Furthermore, this research seeks to provide new insights into mathematics education, specifically focusing on the two-variable linear equation system. By showcasing the effectiveness of integrating the Ethno-Realistic Mathematics Education (Ethno-RME) approach with technological tools, this study aspires to contribute to the field of mathematics education and encourage further innovative practices that enhance students' comprehension and engagement.

Methods

This study employs the design research method with a focus on a validation study type. The primary objective of this method is to address educational problems and develop effective teaching and learning strategies or materials (Plomp, 2013). This method aligns well with the research objectives, which aim to create an innovative learning strategy that integrates student activities with real-life contexts and technology. It is particularly effective for designing the entire learning process, including strategies and tools, unlike other approaches that are limited to the development of a specific product or learning media (Plomp, 2013; van Akker & Nieveen, 2016).

Gravemeijer (2016) outline three stages in the validation study of design research: preliminary design, design experiment, and retrospective analysis. These stages ensure a comprehensive approach to developing and validating innovative educational strategies. The preliminary design phase involves the initial development of the learning strategy, the design experiment phase tests the strategy in practice, and the retrospective analysis phase evaluates the outcomes to refine and improve the approach. This structured method allows for the creation of effective and practical educational solutions that can be applied in real-world settings.

During the preliminary design stage, researchers developed learning activities by conducting a literature review, observing classes, and consulting with teachers and experts. The literature review provided insights into the Ethno-RME approach, the MCM application, and the mathematics education curriculum used in the school. This foundational knowledge helped shape the initial design of the learning activities.

Next, researchers conducted field observations to gather detailed information about student characteristics, classroom conditions, students' abilities, and other factors relevant to classroom learning. These observations ensured that the learning activities were tailored to the specific context of the students and their environment. Additionally, researchers sought input and suggestions from teachers and experts to refine and improve the learning design. This collaborative effort aimed to create a well-rounded and effective educational strategy that integrates real-life contexts with technological tools to enhance students' learning experiences.

The literature review, observations, and discussions informed the creation of a Hypothetical Learning Trajectory (HLT). The HLT encompasses learning activities, objectives, hypothesized student thinking strategies, and potential teacher actions (Simon, 1995).

During the preliminary design phase, researchers also utilized various tools to support learning, including student and teacher books, activity sheets, and math trails in the MCM application. These resources were integral to structuring the HLT, ensuring that the learning activities were well-defined and aligned with educational objectives. By leveraging these tools, the researchers aimed to create a comprehensive and effective learning strategy that integrates real-life contexts and technological aids, thereby enhancing students' engagement and understanding of mathematical concepts.

In the design experiment stage, researchers verify the HLT by implementing the designed learning activities in the classroom. The goal is to test and refine the learning trajectory (Plomp, 2013; van Akker & Nieveen, 2016). This stage provides valuable insights into the effectiveness of the learning activities and allows for adjustments based on classroom observations and student feedback.

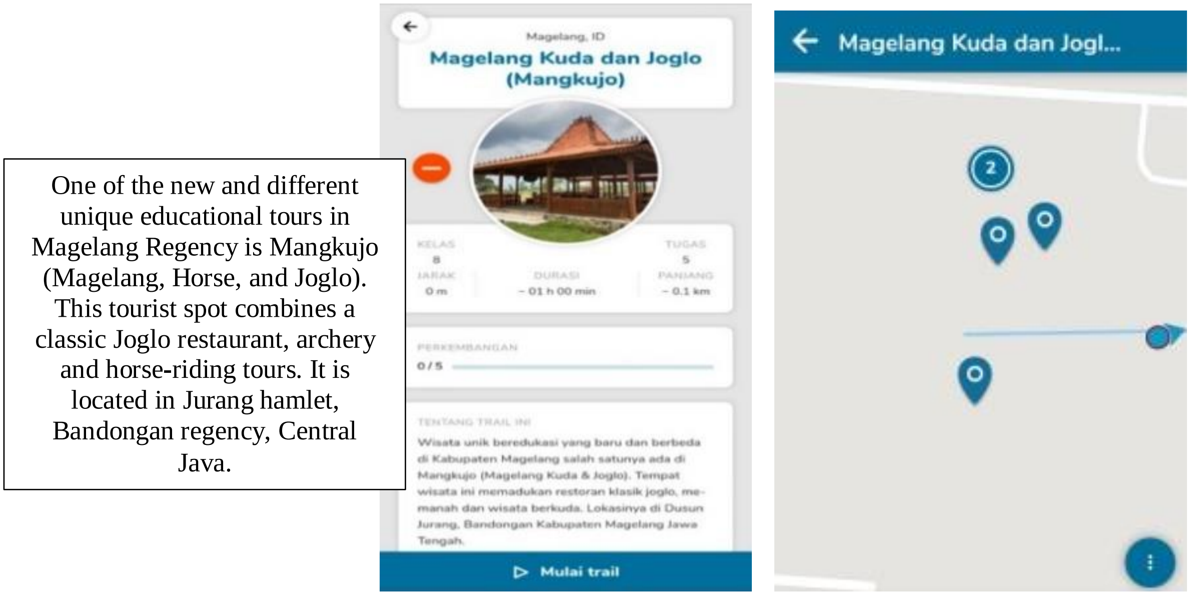
Following the design experiment, the results are analyzed during the retrospective analysis stage. In this phase, researchers compare the actual responses from students during the teaching experiment with the HLT. This comparison helps identify discrepancies, validate successful strategies, and pinpoint areas needing improvement. Finally, the outcomes of this analysis are summarized to address the research questions, offering a comprehensive evaluation of the designed learning approach.

The research was conducted in Mangkujo, an iconic cultural attraction in Magelang City, located in the Bandongan sub-district, Magelang, Central Java. Mangkujo combines a classic Joglo-shaped restaurant with horse riding and archery tours. The Joglo is a traditional Javanese house characteristic of Magelang. Horse riding activities reflect the culture of the Indonesian people, particularly the Magelang community, which has a history of horse riding and archery. The purpose of creating this cultural tourism site is to preserve the local culture and reinforce the identity of the Magelang people.

The construction of the Joglo, gardens, horse riding, and archery arenas in Mangkujo involved the application of various mathematical concepts, including the system of linear equations with two variables. This setting provided a rich context for the research, aligning with the Ethno-RME approach's emphasis on real-life and culturally relevant contexts. By situating the study in such a culturally significant location, the research aimed to connect mathematical learning with the students' cultural and everyday experiences, thereby enhancing their engagement and understanding.

Results and Discussion

The study's results demonstrate the use of Mangkujo objects as a foundation for a learning design focused on the system of linear equations in two variables. The design, called Math Trail Mangkujo, comprises four trails across four locations, starting from the school and ending at Mangkujo. Figure 1 displays the Math Trail Mangkujo design on MCM and the trail route.



(a) (b)

Figure 1. Mangkujo Math Trail on MCM (a) and Trail Route (b)

The Mangkujo Math Trail is meticulously crafted to scaffold students' mathematical reasoning from concrete experiences to abstract concepts. At Trail 1, students engage in practical calculations involving paths and red shoot trees within the school environment, laying the groundwork for understanding variables, coefficients, and constants. This initial phase serves to familiarize students with essential algebraic elements, setting a solid foundation for more complex mathematical exploration. Progressing to Trail 2, students delve into the realm of linear equations with two variables, applying mathematical principles to measure the edges of capsule terrazzo pots in the Mangkujo yard. This stage aims to cultivate students' ability to formulate and interpret algebraic equations within real-world contexts, bridging theoretical knowledge with practical applications.

Trail 3 represents a pivotal advancement in students' mathematical journey by guiding them to identify and analyze linear equations in two variables during visits to the Mangkujo coffee shop. This phase not only enhances their ability to recognize algebraic patterns but also encourages them to apply mathematical reasoning in diverse settings. Finally, Trail 4 challenges students to synthesize their learning by mastering graph plotting and equation solving without reliance on tabular aids, focusing on determining seat prices at Joglo Mangkujo. This culminating experience aims to deepen students' analytical skills and mathematical proficiency, reinforcing their understanding of algebraic concepts through experiential learning. Figure 2 visually illustrates the progression of these trails using iceberg diagrams, showcasing how each stage contributes to a comprehensive educational experience integrating theory and practice.

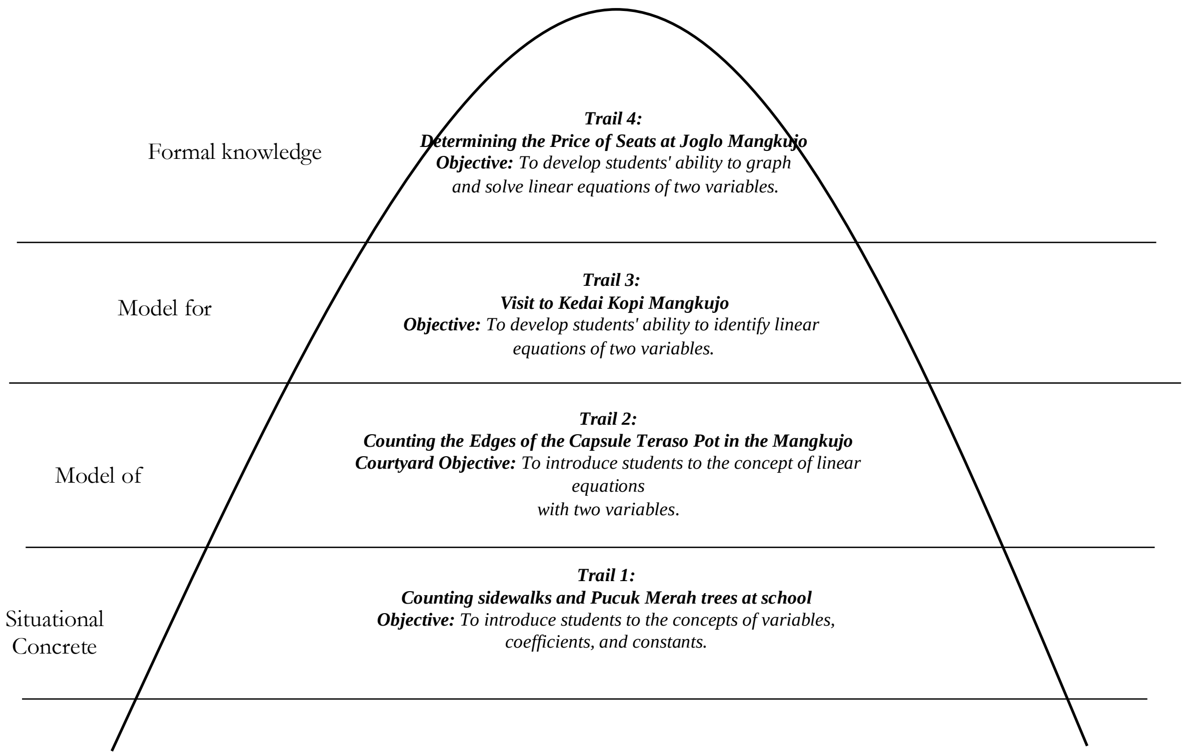
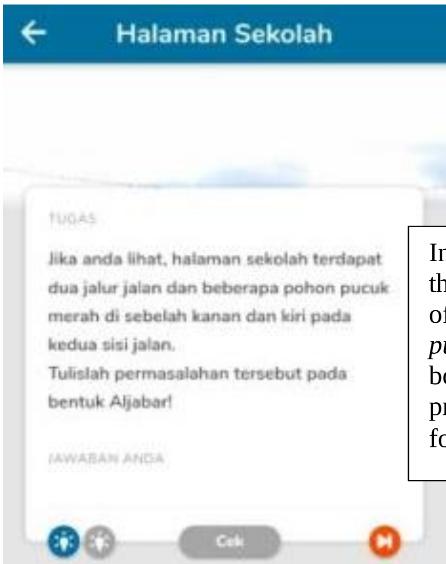


Figure 2. Mangkujo Trail Iceberg

Trail 1: Counting Sidewalks and *Pucuk Merah* Trees at School

The learning design incorporates the Mangkujo trail route, commencing from the school and extending along the highway towards the Mangkujo tourist destination. The trail commences with Trail 1 situated at the school grounds, where students engage in activities such as counting trail paths and identifying *Pucuk Merah* trees. The primary objective of Trail 1 is to familiarize students with foundational algebraic concepts such as variables, coefficients, and constants. Upon reaching the designated GPS point for Trail 1, students are equipped to complete assigned tasks via the MCM platform, as depicted in Figure 3. This integration of location-based tasks not only enhances students' mathematical understanding but also facilitates real-world application of algebraic principles within an interactive learning environment.



In the schoolyard, there are two lanes of road and rows of *pucuk merah* trees on both sides. Write the problem in algebraic form.

Figure 3. Task on Trail 1

Task 1 within the Mangkujo Trail initiative involves a systematic approach to student learning through observation and practical application. Initially, students are tasked with conducting a detailed survey of the school yard, where they count and document the number of trails and red shoot trees present. This exercise serves as a foundational step in introducing students to basic concepts of quantitative analysis and environmental observation within a mathematical context. Following this observational phase, the teacher provides visual aids in the form of pictures depicting the identified trails and trees. Students then apply their findings by affixing these images onto their activity sheets according to specified guidelines outlined in the Mangkujo Trail curriculum. The alignment between the number of pictures attached and the results of their initial counts reinforces students' understanding of mathematical concepts through hands-on, experiential learning methods.

Figure 4 illustrates the dynamic engagement of students in these learning activities, highlighting their active participation in the observational and application phases of Task 1. This visual documentation not only showcases the practical implementation of the Mangkujo Trail's educational approach but also underscores its effectiveness in integrating mathematical learning with real-world observations. By immersing students in tasks that blend theoretical knowledge with practical application, the Mangkujo Trail fosters a deeper comprehension of mathematical principles while nurturing students' critical thinking and analytical skills in a contextualized learning environment.

(a)

(b)

Figure 4. Students are shown counting trees (a) and pasting pictures of trees onto their activity sheets (b)

Furthermore, students are guided to represent trails and trees using symbolic notation, employing letters to denote these elements and indicating their respective quantities based on initial calculations. Under the teacher's supervision, this approach facilitates students' comprehension of fundamental algebraic concepts such as variables, coefficients, and constants. By modeling the trails and trees observed in the school yard through symbolic representation, students not only reinforce their understanding of these abstract mathematical constructs but also develop the ability to differentiate between them more effectively.

This instructional strategy encourages students to engage in symbolic reasoning, linking real-world observations with algebraic symbols. Through this process, students not only deepen their understanding of mathematical concepts but also enhance their problem-solving skills by applying algebraic principles to tangible scenarios. By integrating practical observation with symbolic representation, the Mangkujo Trail not only enriches students' mathematical learning experiences but also cultivates their ability to apply abstract concepts in meaningful contexts.

Figure 5 depicts students' efforts in quantifying the trails and trees observed, showcasing their use of symbolic notation. Students utilized the variables 'p' to denote trails and 'q' to represent trees, assigning numerical values to these variables based on their observational data. This approach allows students to operationalize algebraic concepts within a real-world context, fostering a deeper understanding of variables as placeholders for unknown quantities.

Furthermore, students delineated coefficients as numerical factors accompanying variables ('p' and 'q'), illustrating their role in scaling or modifying the variables' values. In contrast, constants were identified as fixed numerical values that do not vary within the context of their calculations. This analytical breakdown underscores students' grasp of algebraic fundamentals, demonstrating their ability to categorize and apply these concepts effectively in the context of counting and modeling natural elements like trails and trees.

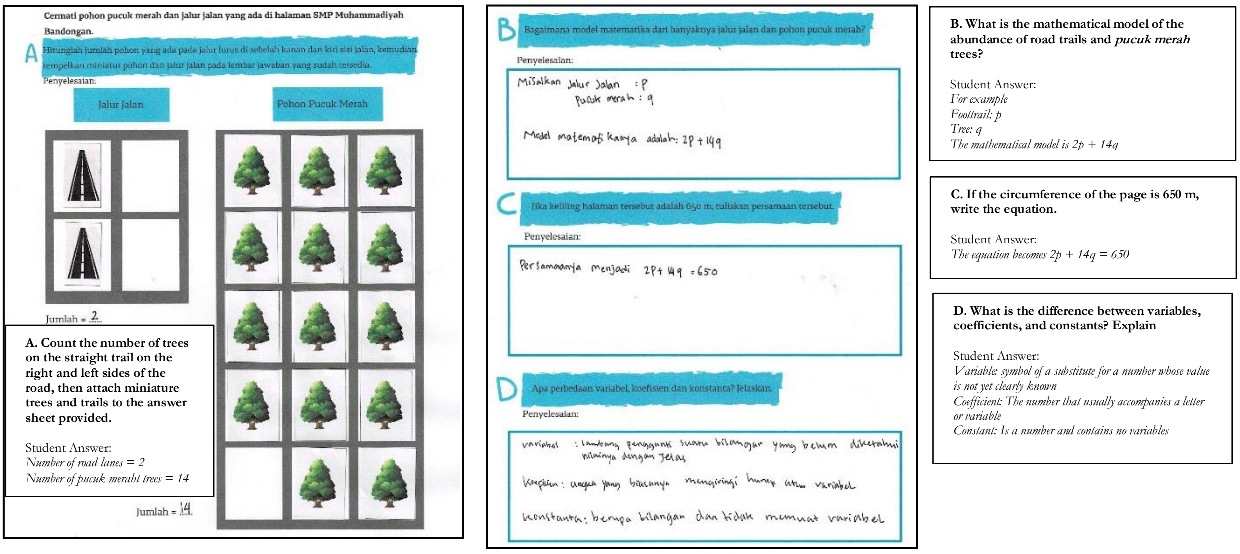


Figure 5. Results of students completing the task on Trail 1

By employing symbolic representation and defining algebraic terms in practical scenarios, the Mangkujo Trail not only enhances students' mathematical literacy but also cultivates their ability to conceptualize and manipulate abstract mathematical constructs. Figure 5 serves as a visual testament to students' engagement and proficiency in integrating observational data with algebraic notation, facilitating a holistic approach to mathematical learning through experiential education.

Trail 2: Counting the Edges of the Capsule Teraso Pot in the Mangkujo Courtyard

Upon completing Trail 1, students advanced to Trail 2, located in Mangkujo Yard, approximately 500 meters from the school and accessible by foot. The primary objective of Trail 2 is to enhance students' proficiency in identifying linear equations in two variables. Students navigate to Trail 2 using the MCM's GPS, arriving at the Mangkujo Courtyard where the Capsule Terrazzo Pot is situated, as indicated on MCM. Following the detailed instructions provided on MCM, students engage in tasks specific to Trail 2. Figure 6 illustrates the task associated with Trail 2.

In Trail 2, students are required to calculate the number of edges on both the base and the capsule of the terrazzo pot. After reading and comprehending the task outlined on MCM and consulting the provided guide, students examine the Teraso pot to ascertain its geometric shape. They then proceed to calculate the number of edges and record their findings on the student activity sheet. This exercise not only reinforces their understanding of geometric properties but also integrates algebraic concepts by connecting real-world objects with linear equations in two variables. Figure 7 depicts the students actively engaged in this activity, highlighting their analytical process and application of mathematical principles in a practical context.

If you notice, there are capsule terrazzo pots to the right and left of the trail to the cashier. How many edges are there on the capsule terrazzo pot and the potting tool?

Figure 6. Task on Trail 2

Figure 7 displays students measuring the edges and base of a pot. After calculating these dimensions, students draw the capsule terrazzo pot and it’s based on the student activity sheet, as shown in Figure 8. Following this, students complete the tasks on MCM and model their calculations as a two-variable linear equation. To create the model, students use the symbol 'r' to represent the capsule terrazzo pot and 's' to represent the base of the pot.

By engaging in these activities, students deepen their understanding of geometric measurements and their application in algebra. Measuring the pot's edges and base reinforces spatial reasoning and connects it with algebraic modeling. The use of symbols 'r' and 's' to represent different components of the pot helps students visualize and formulate linear equations with two variables. This hands-on approach not only aids in grasping theoretical concepts but also enhances problem-solving skills by linking real-world objects with mathematical representation.

Figure 7. Students counting the edges of the capsule Teraso pot and pot base

Figure 8 displays the results of students' drawings of a capsule-shaped terrazzo pot and a block-shaped pot base. According to their calculations, the capsule-shaped pot has 2 edges, while the base has 12 edges. In total, the base of the pots has 48 edges. Additionally, the students observed that there are 4 similar pots in Mangkujo, resulting in a cumulative total of 8 edges when calculated together.

Students can model these calculations as a system of two-variable equations, using the symbols 'r' and 's' to represent the capsule-shaped pot and the pot base, respectively. By doing so, they can identify the correctness of their equations and better understand the concept of a system of two-variable equations. This approach allows students to define and solve equations involving two variables, reinforcing their ability to apply algebraic principles to real-world scenarios and enhancing their analytical skills in interpreting and modeling mathematical relationships.

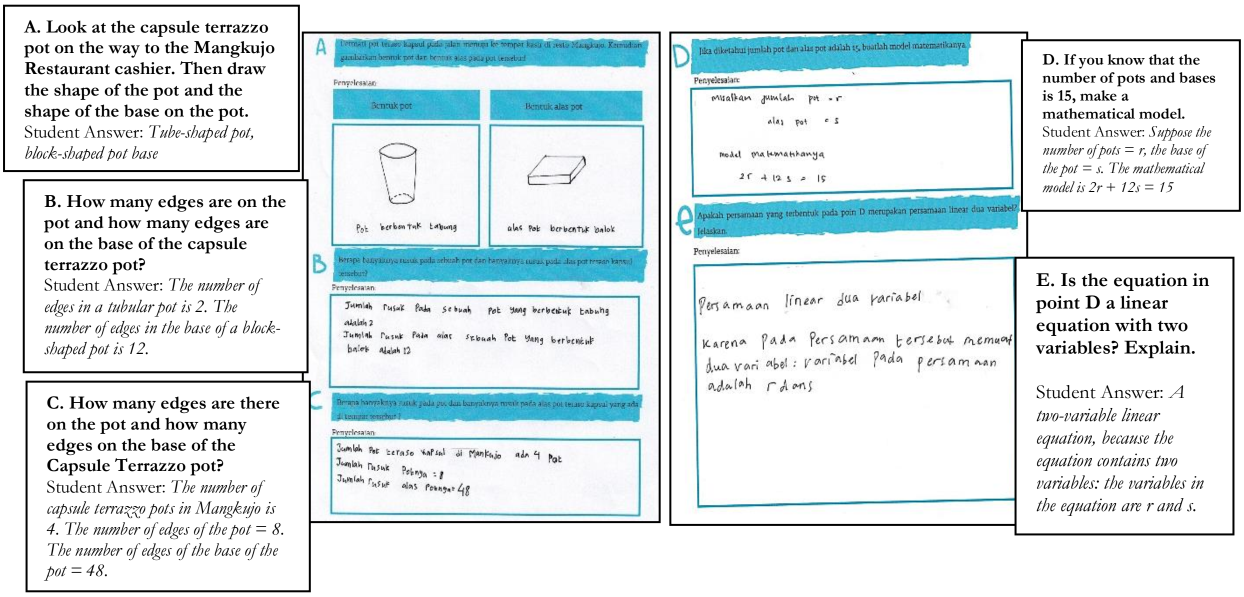


Figure 8. Results of students completing the task on Trail 2

Trail 3: Visit to Mangkujo Coffee Shop

Upon completing Trail 2, students proceed to Trail 3, guided by the instructions on MCM. Trail 3, located at Kedai Coffee Mangkujo, aims to deepen students' understanding of the formal structure of linear equations with two variables. Following the Trail 3 route on MCM, students arrive at the designated trail point and engage in tasks designed to solidify their grasp of linear equations. These tasks require students to write a linear equation for an object with known coefficients, variables, and constants.

Refer to Figure 9 for detailed information on the tasks associated with Trail 3. By working through these exercises, students enhance their ability to formulate and interpret linear equations, strengthening their conceptual understanding of how variables, coefficients, and constants interact within a mathematical framework. This experiential learning approach not only reinforces theoretical knowledge but also cultivates practical problem-solving skills, enabling students to apply algebraic concepts in various real-world contexts.

The pavilion and the cafe are close to each other. If the length and width of the base on a set of tables are 2m and 3m. While the length and width of the base in the Coffee Shop building are 6m and 3m. The length and width of the whole country are 12m and 9m. Make a mathematical model of the problem!

Figure 9. Trail 3 locations at the gazebo and coffee shop

During Trail 3, students will have the opportunity to observe the gazebo and coffee shop table sets located in Mangkujo Yard. Following this observation, students will complete a task on Trail 3 using MCM. The task requires students to measure the length and width of the table set and the coffee shop table, recording the results in the table provided on the student activity sheet.

After gathering these measurements, students will proceed to identify the coefficients and constants associated with their observations, as depicted in Figure 10. This process helps students connect their physical measurements to algebraic expressions, reinforcing their understanding of how coefficients and constants are used to represent real-world dimensions in linear equations. By engaging in this hands-on activity, students not only enhance their measurement and observation skills but also develop a deeper comprehension of the mathematical concepts underlying linear equations with two variables.

(a) (b)

Figure 10. Students record the length and width of the gazebo table set (a) and coffee shop tables (b) on the student activity sheet.

Figure 10 illustrates that students recorded the dimensions of the gazebo table set and the coffee shop table based on the information provided in Trail 3. After documenting these measurements, they identified and listed the coefficients, variables, and constants on the student activity sheet. Finally, students modeled the data as a two-variable linear equation.

The outcomes of the students' work on Trail 3 are presented in Figure 11. This figure showcases how students applied their measurements to create linear equations, demonstrating their ability to translate physical dimensions into algebraic expressions. By engaging in this task, students not only practiced measurement and observation skills but also reinforced their understanding of linear equations and the relationships between coefficients, variables, and constants. This hands-on activity provided a practical application of algebraic concepts, enhancing students' overall comprehension and problem-solving abilities in mathematics.

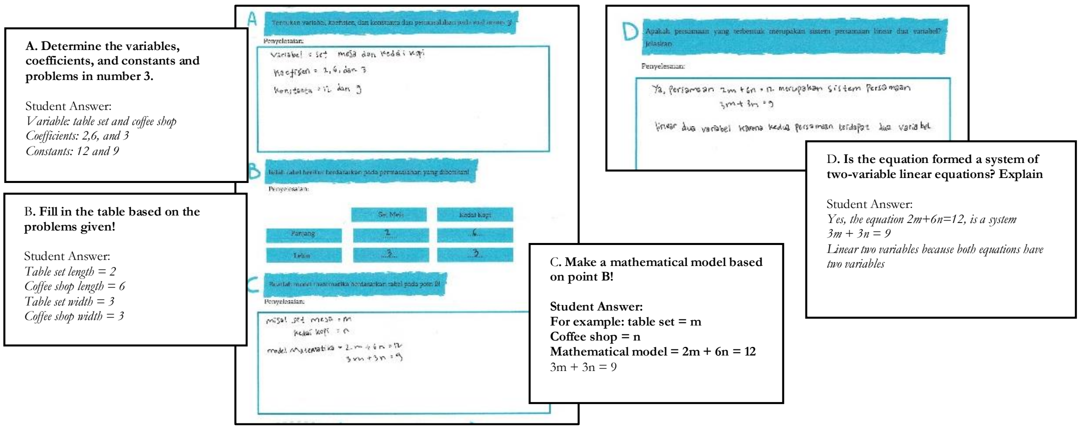


Figure 11. Student outcomes complete assignments on Trail 3

Trail 4: Determining the Price of Seats at Joglo Mangkujo

The fourth trail is located at Joglo Mangkujo. Its purpose is to enhance students' comprehension of graphing linear equations with two variables and solving these equations. Upon reaching the Trail 4 location by following the MCM route, students will engage in tasks designed to deepen their understanding of these concepts.

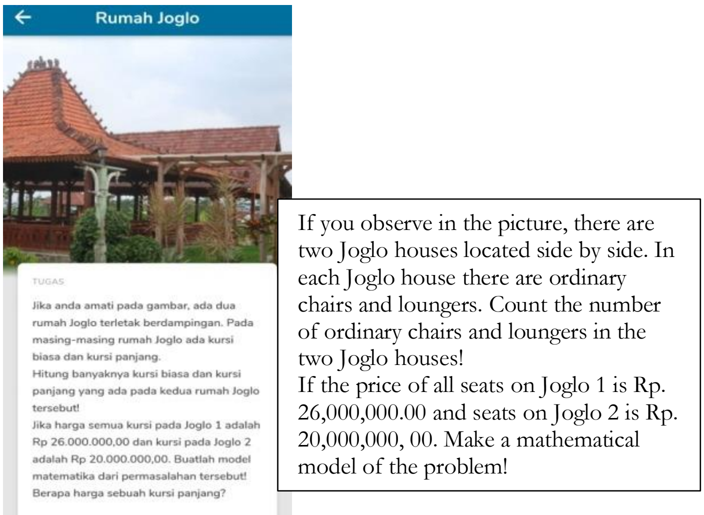


Figure 12. Trail 3 locations in gazebo and coffee shop

As outlined in Figure 12, the tasks will guide students through the process of plotting linear equations on a graph and solving the equations to find their solutions. This activity aims to solidify students' grasp of the graphical representation of linear relationships and their ability to interpret and solve linear equations in a visual format. By participating in this hands-on exercise, students will strengthen their analytical skills and gain confidence in applying mathematical concepts to solve real-world problems.

In Trail 4, students calculate the number of regular and long chairs in Joglo Mangkujo. They then record these results in the table provided on the student worksheet, along with the price of each chair. Using this data, students solve a linear equation with two variables.

Figure 13 illustrates the student activity, highlighting the process of recording the chair quantities and prices, followed by the application of this data to solve the linear equation. This task reinforces students' understanding of how to utilize real-world data in mathematical modeling, enhancing their problem-solving skills and ability to interpret and solve linear equations in practical contexts.

Figure 13. Student activities counting seats at Mangkujo gazebo

After writing a linear equation with two variables, students determine the *x* and *y* coordinates and use them to graph the equation. Finally, they solve the equation to find its solution. Furthermore, Figure 14 shows the results of the students' work, including their determination of the coordinates, the graph of the equation, and the final solution. This activity helps students to visualize the relationship between the variables and understand the process of graphing and solving linear equations. By engaging in this hands-on task, students reinforce their comprehension of algebraic concepts and enhance their ability to apply mathematical reasoning in practical scenarios.

It sounds like Figure 14 illustrates the comprehensive skills and processes students mastered during their work with linear equations of two variables. Students demonstrated proficiency in several key areas: correctly writing linear equations, graphing these equations, and effectively solving them. They applied these skills practically to determine the price of a chair (Rp. 2,500,000) and a short chair (Rp. 500,000).

Moreover, students showed versatility in solving equations through both substitution and graphical methods, including finding solutions by identifying points of intersection on the graph. They engaged in thorough analysis and evaluation of mathematical models derived from narrative problems, transforming these stories into mathematical equations. This process involved converting equations between forms, substituting values, and performing calculations to arrive at final solutions.

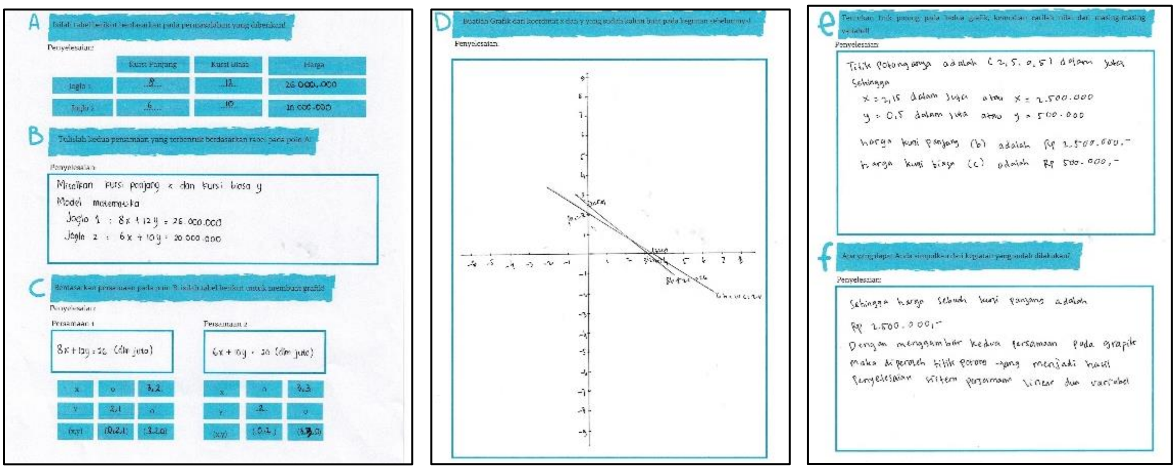


Figure 14. Student outcomes complete assignments on Trail 4

During class discussions, the teacher fostered an interactive learning environment, encouraging students to articulate their problem-solving strategies and validate their answers. This dialogue not only reinforced conceptual understanding but also honed students' ability to apply mathematical methods effectively. Overall, the exercise demonstrated students' proficiency in mathematical modeling, problem-solving, and critical thinking within the context of linear equations with two variables.

Based on the implementation results, the trail-based learning approach using MCM effectively facilitates the learning of systems of linear equations with two variables within the framework of Indonesian mathematics education. This trail serves as an initial step in nurturing students' comprehension of such systems, progressing from real-world contexts to formal mathematical knowledge.

In the first activity, students engage in practical tasks that involve identifying variables, coefficients, and constants. These activities include counting trees and road lines, attaching miniature representations of these elements, and completing related tasks on the MCM application. This hands-on approach aids in developing students' familiarity with algebraic concepts in an informal setting, laying the groundwork for deeper understanding.

The second activity focuses on constructing linear equations with two variables. Students draw upon their observations from the real-world context, such as measuring and calculating the dimensions of objects like the capsule terrazzo pot and its base. This activity not only enhances students' grasp of linear equations but also fosters their ability to create mathematical models based on empirical data. These activities within the trail-based learning context play a pivotal role in bridging real-world experiences with formal mathematical concepts. They promote active learning, problem-solving skills, and a deeper understanding of algebraic principles, aligning with the objectives of Indonesian mathematics education to provide meaningful and contextualized learning experiences.

The third activity involves constructing a system of linear equations with two variables. Within the trail context, this activity plays a crucial role in deepening students' understanding of such systems in an informal manner. Students identify variables, coefficients, and constants based on the trail's scenarios within the MCM application. Additionally, this activity helps students develop their ability to formulate mathematical models and discern between problems that involve systems of linear equations with two variables and those that do not.

The fourth activity focuses on solving a system of linear equations with two variables using graphical methods. The trail's context supports students in understanding how to graphically solve such problems informally. Students use tables provided in the Student Activity Worksheet to organize data, facilitating the creation of mathematical models. Moreover, this activity enhances students' proficiency in interpreting graphs and determining points of intersection between two lines as solutions to problems presented within the trail.

The fifth activity centers on solving a system of linear equations with two variables using the substitution method. The trail's context is instrumental in guiding students through this method, which involves transforming one equation into a more manageable form. This process aids students in creating mathematical models, solving for the value of y, substituting it back into the equation to find the value of x, and ultimately deriving solutions to the problems posed.

Overall, these sequential activities within the trail-based learning approach provide a comprehensive framework for students to engage deeply with systems of linear equations with two variables. They promote hands-on learning, critical thinking, and the practical application of algebraic principles within meaningful real-world contexts, aligning with the goals of Indonesian mathematics education to foster robust mathematical reasoning and problem-solving skills.

The study's approach to math learning and problem-solving is designed to emulate real-life situations found in the local environment. This methodology aligns with Ludwig and Jesberg’s (2015) MCM trail, which leverages modern technological tools like smartphones to engage students in mathematical activities beyond traditional classroom settings. Mathematical tasks are presented using images, GPS coordinates, and contextual problems (Barlovits & Ludwig, 2020), enabling students to navigate and solve problems based on their own observations and interactions. This approach not only enhances the relevance of learning by grounding mathematical concepts in practical scenarios but also fosters deeper engagement and real-world applications of mathematical principles.

The math tasks within the trail problems are meticulously designed to connect directly with real-world objects, providing students with practical learning experiences that actively engage them in learning activities. Each task within the trail features varying levels and types of mathematical problems, typically requiring concise answers (Cahyono et al., 2015). Additionally, the student workbook includes several questions aimed at reinforcing understanding of systems of linear equations with two variables. These questions prompt students to develop their thinking strategies regarding this concept, ensuring alignment with the teaching and learning processes.

Through retrospective analysis, it has been observed that the learning design of the two-variable linear equation system within the context of trail problems in the MCM application has significant potential to enhance students' mathematical skills. This design incorporates principles and characteristics of Ethno-RME, which aim to guide students towards higher-order thinking skills by encouraging active engagement and relating content directly to their environment (Prahmana, 2022; Prahmana et al., 2023). By integrating Ethno-RME principles into the learning design, students are encouraged to think critically and apply mathematical concepts in meaningful contexts.

Moreover, using media such as MCM captures students' attention and enhances their interest in learning mathematical concepts. This approach not only makes learning more engaging but also facilitates deeper understanding and application of mathematical principles in real-world scenarios. Overall, the combination of Ethno-RME principles and modern technological tools in the learning design of systems of linear equations with two variables proves effective in promoting students' cognitive development and fostering a positive learning experience.

The context of trail problems within the MCM application plays a pivotal role in facilitating students' understanding of systems of linear equations with two variables. By immersing students in real-world contexts, these trail problems foster the development of critical thinking skills essential for problem-solving in their environment (Rocha et al., 2024; Smith et al., 2023). Students are actively engaged in observing and resolving diverse mathematical challenges, using their cognitive abilities to derive solutions (Aliyu et al., 2023).

Throughout the learning process, student activities are designed to cultivate a desire for learning, involving both physical and intellectual participation (Basri et al., 2019). By following the trail in MCM, students experience meaningful learning moments where they apply higher-order thinking skills to tackle mathematical problems presented in authentic settings (Paramitha & Agoestanto, 2023). This active involvement enables students to connect theoretical knowledge with practical applications, reinforcing their understanding of mathematical concepts.

Integrating real-life situations into the mathematics learning process, particularly through technologies like MCM, enhances student engagement and comprehension. Utilizing smartphones and other modern devices empowers students to apply mathematical skills outside the classroom, aligning with the principles of Ethno-RME. This approach not only makes learning relevant and meaningful but also equips students with problem-solving abilities applicable in real-world scenarios.

The design of mathematical tasks within trail problems effectively bridges abstract concepts with tangible objects, promoting hands-on experiences and direct engagement in learning activities. By embedding these tasks in real-world contexts, such as those found in the MCM application, students are encouraged to apply their higher-order thinking skills to analyze and solve problems of varying complexity. This approach supports a holistic approach to mathematics education by nurturing students' cognitive growth and preparing them to apply their learning effectively in diverse settings.

Furthermore, the incorporation of Ethno-RME principles into instructional design underscores the importance of contextual relevance and active student participation in developing mathematical understanding. By immersing students in the context of trail problems within MCM, this study facilitates the development of critical thinking skills necessary for problem-solving across different environmental contexts. Research findings demonstrate that engaging students in active learning activities, which encompass both physical and cognitive components, enhances their motivation to learn and deepens their comprehension of mathematical concepts.

As students navigate the pathways in MCM, they are encouraged to become more meaningful learners by applying their higher-order thinking skills to solve mathematical problems rooted in real-world scenarios. Meaningful learning occurs when learners actively connect new information to prior knowledge, fostering engagement, and facilitating effective knowledge retention and transfer (Andrews et al., 2023). Moreover, the inclusion of contextual trail problems in MCM, alongside Ethno-RME principles, plays a pivotal role in fostering mathematical thinking and enhancing understanding of systems of linear equations with two variables. This integrated approach not only enriches the learning experience but also equips students to confidently tackle mathematical challenges they encounter in their environment.

The research presented explores a novel approach in mathematics education by integrating Ethno-RME principles with the MCM application, focusing specifically on teaching systems of linear equations with two variables through trail-based learning. This methodology stands out due to its innovative use of technology to immerse students in real-world contexts, where they apply mathematical concepts to practical scenarios encountered along mapped trails. By integrating Ethno-RME, which emphasizes contextual relevance and cultural familiarity in learning, the study bridges abstract mathematical concepts with tangible objects and environmental settings. This approach not only enhances students' understanding of systems of linear equations but also cultivates critical thinking and problem-solving skills essential for navigating complex mathematical challenges in everyday life. Moreover, the research positions itself at the forefront of educational innovation by leveraging modern technological tools like MCM to create interactive learning experiences that engage students actively in the learning process.

Comparatively, recent studies have increasingly focused on integrating technology in mathematics education to enhance student engagement and learning outcomes (Abu & Kribushi, 2022; Su et al., 2022; Sunzuma, 2023; Gopinathan et al., 2022; Greener, 2022). This research aligns with current educational trends by emphasizing hands-on, experiential learning through trail-based activities within a digital platform. By linking mathematical tasks to physical environments and leveraging digital mapping tools, the study provides students with practical applications of mathematical theories, thus making learning more meaningful and relevant. Furthermore, the emphasis on developing higher-order thinking skills in problem-solving, particularly within the context of systems of linear equations, underscores the research's contribution to advancing cognitive development in mathematics education. By situating mathematical learning in familiar contexts and integrating technological resources effectively, the study not only enriches educational practices but also prepares students to apply their mathematical knowledge proficiently in diverse real-world situations, thereby enhancing their overall learning experience and skill acquisition.

Conclusion

This study highlights the importance of the context of trail problems in the understanding of the concept of the system of linear equations of two variables for learners, with a focus on the Ethno-RME approach. The results demonstrated that the trail problem context significantly contributed to students' understanding of mathematical concepts related to the system of linear equations of two variables. The research findings indicate that the context of trail problems, including the schoolyard, the terrazzo pot capsule in Mangkujo, the length and width of the gazebo and coffee shop, and the number of chairs in the Joglo Mangkujo house, provided valuable learning experiences for students in understanding the concept. However, it is important to note that this study has some limitations. Firstly, the research sample may be limited to one particular school or region, which may limit the generalizability of the results to a wider population. Secondly, the use of the Indonesian mathematics realistic education approach may require special training for teachers in its implementation, which may require additional consideration in its use in various learning contexts.

For future research, it is recommended that more representative samples from various student and school backgrounds be included. Additionally, further research can explore the effectiveness of various other learning approaches that can be used in conjunction with the context of trail problems in learning the system of linear equations of two variables. Further research could also consider other factors that may influence students' understanding of the mathematics concept, such as students' learning motivation and learning style. This would provide deeper insights into the role of trail problem context in mathematics learning and its contribution to students' understanding of the concept of a system of linear equations of two variables.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript. Furthermore, ethical considerations, including plagiarism, misconduct, data fabrication and/or falsification, duplicate publication and/or submission, and redundancies, have been thoroughly addressed by the authors.

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