26 (1), 2025, 556-569
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Enhancing Mathematical Thinking Skills through Realistic Mathematics Education Assisted by an Ethnomathematics Mobile Module

Ratri Rahayu[1,*], Marizka Aulia Fahma[1], Henry Suryo Bintoro[1], & Alif Catur Murti[2]
[1]Mathematics Education Study Program, Universitas Muria Kudus, Indonesia
[2]Informatics Engineering Study Program, Universitas Muria Kudus, Indonesia

Abstract: This study addresses the deficiencies in students' mathematical thinking skills. A preliminary assessment of 69 students yielded a mean score of 21.32. The study examined enhancing students' mathematical thinking skills through the Realistic Mathematics Education (RME) model, supported by the ethnomathematics mobile module. This quantitative research employs a quasi-experimental design. The researchers collected data using a mathematical thinking skills test and analyzed it through an independent sample t-test and N-gain test. The findings indicate a significant improvement in the experimental group's posttest mean score, which increased to 80.72, surpassing the control group's posttest mean score of 69.49. The results confirm a significant difference in mathematical thinking skills between students taught using the RME approach with the ethnomathematics mobile module and those instructed through traditional lectures. The pretest-posttest data for the experimental group yielded an N-gain score of 0.59, classified as moderate. The study concludes that implementing the RME model with the ethnomathematics mobile module effectively enhances seventh-grade students' mathematical thinking skills in data presentation. The findings suggest that the ethnomathematics mobile module should be incorporated into other mathematical topics to support students' learning further.

Keywords: ethnomathematics mobile module, mathematics thinking skills, RME.

▪ INTRODUCTION

Mathematics is a fundamental subject at every educational level, from primary school to senior high school (Henry Suryo Bintoro et al., 2022a; Wangdi et al., 2023). Every individual must acquire mathematical knowledge, as it remains essential across all levels of education, from primary to junior high school (Genc & Erbas, 2019). Mathematics involves comprehending and applying memorized concepts. Students must not only acquire mathematical knowledge but also understand and master problem-solving methods, progressing from basic to complex levels (R. Rahayu et al., 2023). Mathematical learning requires students to develop logical reasoning and systematic problem-solving abilities. Additionally, students must cultivate their potential to the fullest extent through structured education. Consequently, effective mathematics instruction necessitates understanding concepts, articulating ideas, solving problems, and recognizing the broader significance of mathematics. The primary objective of mathematics education is to develop students' mathematical thinking skills.

Efforts to enhance educational quality and student competencies must prioritize the development of mathematical thinking skills. These skills require students to gather information inductively and deductively, analyze data, generalize concepts, and integrate newly acquired knowledge (Gunawan et al., 2022). Mathematical thinking comprises four core indicators: specializing, generalizing, conjecturing, and convincing (Stacey et al., 2010).

Ratri Rahayu
*Email: ratri.rahayu@umk.ac.id

DOI: http://dx.doi.org/10.23960/jpmipa/v26i1.pp556-569
Received: 18 March 2025
Accepted: 13 April 2025
Published: 06 May 2025

Both mathematical thinking skills and student autonomy play crucial roles in mathematics education (H. S. Bintoro et al., 2021; Ukobizaba et al., 2021). However, many students struggle with mathematical problem-solving due to insufficient mathematical thinking skills. This deficiency often results from a curriculum that fails to foster higher-order thinking skills. Additionally, the learning environment may contribute to these challenges (Ferita & Fitria, 2019).

Beyond cognitive challenges, mathematics education in schools faces methodological and technological limitations. Many institutions have yet to implement the Realistic Mathematics Education (RME) model. Instead, most classrooms rely on printed textbooks without incorporating digital learning tools (Ratri Rahayu et al., 2023). Schools predominantly employ direct instructional methods, emphasizing lecturing and task-based strategies. Direct instruction prioritizes procedural and declarative knowledge (Tobia et al., 2021). While teachers encourage students to engage with the material and achieve learning objectives, lecture-based instruction limits active student participation. This model primarily requires students to listen, take notes, and complete assigned exercises, restricting opportunities for interactive learning. As a result, many students struggle to retain information and experience difficulty solving diverse and complex problems. The lack of engagement often leads to boredom, as observed in school-based studies (Ai hui et al., 2020).

Educators must implement engaging and interactive learning methods to address the limitations of lecture-based instruction. These methods should encourage student participation and enhance academic achievement. Effective instruction considers students' individual characteristics, enabling teachers to facilitate learning and achieve broader educational objectives (Ulya et al., 2019). One instructional approach that enhances mathematics education is the Realistic Mathematics Education (RME) model, which improves learning outcomes, goal attainment, and instructional processes.

The RME model actively engages students in problem-solving and fosters a student-centered approach to mathematics education. This method enables students to recognize connections between mathematical concepts and real-life applications, strengthening their understanding of how mathematics functions within their communities (Chisara et al., 2018). The foundation of RME rests on the principle that mathematics is a human activity, requiring its application in daily life, mathematical contexts, and imaginary scenarios to support cognitive development. This model promotes equal learning opportunities and facilitates mathematics instruction through contextualized problem-solving (Nashrullah et al., 2021). The RME learning process consists of five key stages: (1) presenting contextual problems, (2) encouraging independent problem-solving, (3) fostering interaction, (4) facilitating discussion and comparison of solutions, and (5) drawing conclusions (Armiati et al., 2022). By implementing RME, educators provide students with structured opportunities to expand their mathematical knowledge and develop critical thinking skills (Ardiyani et al., 2018).

In addition to instructional models, digital learning media significantly influence students' mathematical thinking skills. The Fourth Industrial Revolution (Industry 4.0) has introduced an era in which interconnected digital technologies shape education (Syamsuar & Reflianto, 2018). Android-based learning resources, such as ethnomathematics mobile applications, serve as effective digital tools for contemporary students who prefer interactive media over traditional textbooks (Haleem et al., 2022).

An ethnomathematics mobile module facilitates meaningful learning experiences by enabling students to develop a more profound understanding of abstract mathematical concepts. This approach helps them construct knowledge through tangible, real-world contexts (Gargrish et al., 2020).

Designed to support seventh-grade students, the ethnomathematics mobile module facilitates students master data presentation concepts in an engaging and comprehensible manner. This application includes instructional materials on statistical data, data representation, and data interpretation through tables and diagrams. Its interface features a homepage and various menu options, including hints, learning objectives, instructional content, exercises, and information about the application's developers. A key advantage of this Android-based tool is its ability to integrate local cultural elements, allowing students to develop mathematical competence while deepening their appreciation of their heritage.

The RME model follows a structured progression that guides students from problem identification to practical application. This process fosters conceptual understanding by providing students with opportunities to apply their knowledge to mathematical problems. The ethnomathematics-based module reinforces this approach by incorporating cultural elements into mathematical instruction, ensuring that students remain connected to their local traditions. Ethnomathematics represents the intersection of mathematical concepts and cultural practices, integrating traditional knowledge into formal mathematics education (Payadnya et al., 2024). By linking mathematical instruction to cultural contexts, RME enhances students' ability to comprehend and apply mathematical principles in real-life situations. Incorporating ethnomathematics into mathematics education improves students' understanding because it situates mathematical concepts within familiar cultural experiences (Verner et al., 2019). This approach strengthens specific competencies and enhances overall learning outcomes (Aisy et al., 2021; Supiyati et al., 2019). Ethnomathematics instruction encourages students to engage with real-world issues, cultural heritage, community practices, environmental challenges, and effective pedagogical strategies, thereby enriching their mathematical proficiency. The ethnomathematics mobile module specifically integrates cultural elements from Kudus, including traditional architecture, local cuisine, and regional customs, fostering a culturally relevant approach to mathematics education.

The implementation of the Realistic Mathematics Education (RME) model, supported by the ethnomathematics mobile module, plays a crucial role in developing students' mathematical thinking skills. The ethnomathematics mobile module presents contextual problems within the exercise menu, aligning with real-life situations and cultural aspects of Kudus. Students begin by reading and analyzing these problems individually before formulating their solution strategies. They must connect mathematical concepts learned from the application and determine the most effective approach to solving the problems. At this stage, students develop confidence in their abilities and learn to manage problem-solving challenges independently.

During the interaction phase, students engage in discussions to refine their solutions, working both individually and collaboratively to determine the most appropriate answers. In the subsequent step of comparing and discussing solutions, students evaluate and contrast their responses to the given problems. Finally, in the concluding stage, they synthesize the material discussed and consolidate their understanding. Before implementing the developed application, researchers ensured its alignment with the RME approach. Consequently, the ethnomathematics mobile module was systematically integrated with the RME methodology to enhance its instructional effectiveness.

By following the structured steps of the RME approach, researchers aimed to foster active participation in mathematics learning. The RME model enables students to recognize the relationship between mathematics and real-world scenarios, allowing them to understand its practical applications in human activities. To maximize the effectiveness of instruction, educators must employ appropriate teaching methodologies and incorporate digital learning tools such as Android-based applications.

This study examined the enhancement of students' mathematical thinking skills through the RME learning model assisted by the ethnomathematics mobile module. The research sought to address the following questions: (1) Is there a significant difference in the mathematical thinking skills of students taught using the RME approach assisted by the ethnomathematics mobile module compared to those taught using the lecture method? (2) What are the criteria for assessing improvements in students' mathematical thinking skills when taught using the RME approach assisted by the ethnomathematics mobile module? (3) Does the improvement in mathematical thinking skills differ between students taught using the RME approach assisted by the ethnomathematics mobile module and those taught using the lecture method?

▪ METHOD

Participants

The current research site was at one Public Junior High School (JHS) in Kudus, Indonesia, in 2023. The research population comprised 283 seventh-grade students enrolled at the school. The study employed purposive sampling, selecting 35 students for the experimental group and 34 students for the control group.

Research Design and Procedures

This quasi-experimental design used a non-equivalent pretest-posttest control group structure. A quasi-experimental design was selected because the research was conducted within an existing school setting, making it impractical to form new classes. In quasi-experimental research, students can be assigned to control and experimental groups; however, the selection of participants for each group is not conducted randomly (Creswell, 2014). The research procedure began with administering a pretest to assess students' initial mathematical thinking skills. The experimental group received instruction using the RME approach supported by an ethnomathematics-based Android application, while the control group received instruction through direct learning. Both groups studied the same mathematics topic: data presentation. After completing the instructional phase, students took a posttest to evaluate their progress.

Instrument

The researchers assessed students' mathematical thinking skills using a written test. The test was administered as a closed-book assessment, with smartphone use prohibited. The test items focused on data presentation and consisted of a pretest and a posttest, each containing four questions designed to evaluate key mathematical thinking skills: specializing, generalizing, conjecturing, and convincing. The pretest was administered before instruction commenced, while the posttest was given upon completion of the learning sessions. Students were allotted 60 minutes to complete each test.

The researchers employed expert judgment to ensure the content validity. A validation questionnaire was used to evaluate three key aspects: material relevance, structural coherence, and linguistic clarity. Two mathematics education lecturers served as expert validators, while a junior high school mathematics teacher contributed as a practitioner validator. The final analysis of the validation questionnaire produced an average score of 65.78, indicating that the instrument met feasibility criteria. Furthermore, an empirical reliability analysis was conducted using the Cronbach's alpha formula, yielding a reliability coefficient of r = 0.93, which classified the instrument as highly reliable.

Data Analysis

The data analysis included an evaluation of the pretest and posttest results from both the experimental and control groups. Prerequisite tests, including normality and homogeneity tests, were conducted to verify statistical assumptions. An independent-samples t-test was performed to determine whether significant differences existed in the mathematical thinking skills of students in the two groups. Statistical calculations were conducted using SPSS 26, and N-gain analysis was employed to measure the improvement in students' mathematical thinking skills. Table 1 shows the interpretation resultsof N-gain based on Lestari & Yudhanegara (2017).

$$N.Gain = \frac{posttest\ score - pretest\ score}{ideal \max score - pretest\ score}$$

Table 1. Enhancement criteria with N-gain score

N-Gain Score	Criteria
N-gain $\geq$ 0.70	High
0.30 $<$ N-gain $<$ 0.70	Moderate
N-gain $\leq$ 0.30	Low

▪ RESULT AND DISSCUSSION

The learning process follows the five stages of Realistic Mathematics Education (RME): providing contextual problems, solving problems independently, creating interaction, comparing and discussing solutions, and drawing conclusions (Chisara et al., 2018).

In the first stage, the teacher presents contextual problems using the ethnomathematics mobile module, ensuring that the problems align with real-life applications. During the second stage, students independently solve the given problems by employing their strategies to determine the most effective solution. The third stage involves student interactions with peers and teachers to explore potential solutions collaboratively. In the fourth stage, students engage in discussions with their desk mates or group members to compare and refine their answers. This process continues with class-wide presentations, allowing students to evaluate different problem-solving approaches. Finally, in the fifth stage, the teacher guides students in reviewing the material. At the end of the session, students do an independent evaluation by answering questions in the ethnomathematics mobile module.

The ethnomathematics mobile module is an Android-based educational application designed to support mathematics learning. This application includes features such as learning indicators, basic competencies, and clearly defined learning objectives related to flat-sided spatial geometry. Each learning activity incorporates ASEP (apperception), JAYA (cultural bridge), SITI (material description), and EDI (self-evaluation). A distinctive feature of this application is its integration of Kudus' cultural heritage, providing students with a culturally relevant learning experience.

Figure 1. Main page of ethnomathematics mobile module

Figure 2. Evaluation page of ethnomathematics mobile module

Description of Pretest and Posttest Data

The research was conducted on 35 students on experimental group and 34 students in control group by analyzing mathematics thinking skills before (pretest) and after (posttest) learning. The applied final data analysis refers to the pretest-posttest result analysis. Table 2 shows the recapitulation of the pretest-posttest of both groups.

Table 2. The final data recapitulation

Data	Experimental group	Control group
N	35	34
Max pretest	88	69
Min pretest	25	44

$\bar{X}$ pretest	52.68	55.15
Standard deviation	19.45	13.73
Max posttest	100	94
Min posttest	56	44
$\bar{X}$ posttest	80.71	69.49
Standard deviation	15.85	17.42

Table 2 shows the pretest of students' mathematics thinking skills in the experimental group is 52.68 lower than the pretest result of the control group, 55.15. After receiving the RME approach assisted with the ethnomathematics mobile module, the mean score of the experimental group posttest increased to 80.72 higher than the control group's posttest result, 69.49.

Results of the Effectiveness Test

The efficacy of the Realistic Mathematics Education (RME) model, supported by the ethnomathematics mobile module, was assessed using statistical analyses, including the normality test, homogeneity test, independent sample t-test, and N-gain test. The normality test results, conducted using the Kolmogorov-Smirnov test at a significance level of 0.05, yielded values of 0.156 > 0.05 for the experimental group and 0.064 > 0.05 for the control group. These results indicate that the initial data distribution of students' mathematical thinking skills was normal. Subsequently, the homogeneity test, conducted at a significance level of 0.04, produced a significance value of 0.852 > 0.05 for both groups, confirming that the variances were homogeneous. Since the prerequisite tests demonstrated normality and homogeneity, further data analysis employed parametric statistical methods.

The independent sample t-test assessed differences in mathematical thinking skills between students taught using the RME approach with the ethnomathematics mobile module and those instructed through the lecture method. The null hypothesis ("H" _0) for the first hypothesis posited no significant differences existed between the groups $\mu_1 = \mu_2$, while the alternative hypothesis ("H" _1) suggested a significant difference $\mu_1 \neq \mu_2$. The results of the SPSS 26 calculations indicate a sig. (2-tailed) is 0.000 < 0.05, leading to the rejection of H0H_0H0. These findings confirm significant differences in mathematical thinking skills between students who received instruction through the RME approach with the ethnomathematics mobile module and those taught using the lecture method.

The implementation of RME, assisted by the Android-based ethnomathematics mobile module, significantly influenced the posttest results of students' mathematical thinking skills in the domain of data presentation. The posttest scores revealed an average of 80.71 for the experimental group, categorized as "very excellent," while the control group attained an average score of 69.49, categorized as "excellent." These findings indicate that the RME model, supported by the ethnomathematics mobile module, effectively enhanced students' mathematical thinking skills, particularly in solving concrete mathematical problems related to data presentation. Tunjungsari & Tasyanti (2017) and Zuliana et al. (2020) also identified significant improvements in mathematical thinking skills among students instructed using the RME model compared to those taught without it. Additionally, previous research demonstrated that integrating ethnomatematics into learning fosters mathematical thinking skills and improves learning outcomes (Henry Suryo Bintoro et al., 2021; Mogari, 2014; R Rahayu et al., 2018; Utami et al., 2019).

Before the intervention, both groups exhibited relatively similar pretest scores. The experimental group achieved an average pretest score of 52.68, while the control group attained an average score of 55.15. These results indicate that both groups initially possessed comparable levels of mathematical thinking ability. The experimental group demonstrated a more substantial improvement in posttest scores than the control group. The experimental group achieved a posttest average of 80.71, while the control group reached 69.49. Although both groups experienced score increases, the improvement was more pronounced in the experimental group, highlighting the greater impact of the intervention.

These findings lead to the conclusion that the implementation of the RME model, supported by the ethnomathematics mobile module, significantly enhanced students' mathematical thinking skills more effectively than the traditional lecture method. Thus, the intervention applied to the experimental group served as the primary factor contributing to the observed improvement in students' mathematical reasoning abilities. Figure 3 illustrates the comparative increase in mathematical thinking skills between the experimental and control groups.

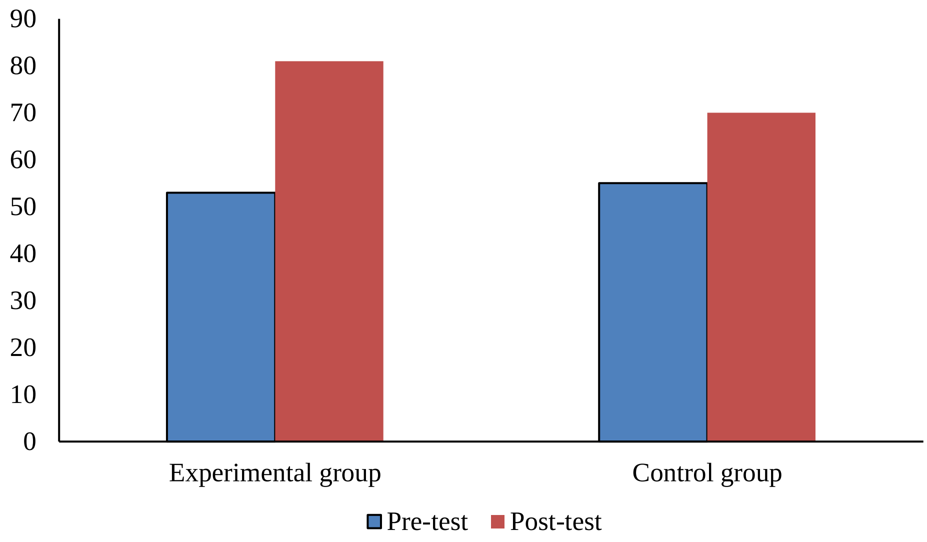

Figure 3. Pretest and posttest results

The N-gain value for the experimental group was 0.59, categorized as moderate, while the control group obtained an N-gain value of 0.31, also classified as moderate. The researchers subsequently analyzed the data using an independent sample t-test to compare the N-gain values between the two groups. The SPSS calculations indicated a significance value of 0.000 < 0.05, leading to the rejection of H0. These results confirm a statistically significant difference in the improvement of mathematical thinking skills between students who received instruction through the RME model assisted by the ethnomathematics mobile module and those taught using the lecture method.

The findings demonstrate a substantial enhancement in the mathematical thinking skills of both groups. The recapitulation of the initial data supports the hypothesis test results. The experimental group initially attained an average pretest score of 52.68, which improved to 80.71 after the intervention. Similarly, the control group's pretest score averaged 55.15, increasing to 69.49 following the application of the RME approach. The researchers conducted further analyses using the N-gain test and the independent sample t-test. The N-gain test was employed to measure the degree of improvement before and after the intervention. The experimental group achieved an N-gain score of 0.59, categorized as moderate, indicating significant improvement in mathematical thinking skills due to the RME approach supported by the ethnomathematics mobile module. Conversely, the control group's N-gain score of 0.31, also categorized as moderate, suggests an improvement in mathematical thinking skills, albeit to a lesser extent.

The researchers further analyzed the improvement in mathematical thinking skills across four indicators: specializing, generalizing, conjecturing, and convincing. The implementation of the RME model, assisted by the ethnomathematics mobile module, had varying impacts on each indicator.

For the specializing indicator, the pretest score increased substantially from 45 to 93.5 in the posttest. This significant improvement indicates that the RME approach, supported by the ethnomathematics mobile module, effectively enhanced students' ability to identify specific patterns and characteristics within mathematical concepts. The integration of cultural contexts into learning appeared to facilitate students' comprehension and connection of abstract mathematical ideas to real-world experiences.

In contrast, the generalizing indicator exhibited a slight decline from 83.5 in the pretest to 77.25 in the posttest. This decrease suggests that although students demonstrated proficiency in understanding mathematical concepts within specific contexts, they encountered difficulties in extending their comprehension to broader generalizations. The culture-based approach employed in ethnomathematics may have led students to concentrate more on specific cases rather than recognizing overarching mathematical patterns.

The conjecturing indicator showed a notable increase from 52.75 in the pretest to 83.5 in the posttest. This improvement suggests that the RME model effectively encouraged students to engage in mathematical reasoning by formulating hypotheses based on observed cultural patterns.

Similarly, the convincing indicator exhibited a significant increase from 29.25 in the pretest to 68.5 in the posttest. This progress indicates that students became more adept at articulating and justifying their mathematical conjectures. The ethnomathematics mobile module likely provided interactive and visual support, which facilitated students' ability to comprehend and communicate mathematical concepts more effectively.

Overall, the implementation of the RME model, supported by the ethnomathematics mobile module, demonstrated effectiveness in enhancing most indicators of mathematical thinking skills. The substantial improvements in specializing, conjecturing, and convincing suggest that this approach successfully fostered students' conceptual understanding, reflective thinking, and ability to communicate mathematical arguments. However, the decline in the generalizing indicator highlights potential challenges in transferring knowledge from specific cultural contexts to broader mathematical generalizations. These findings provide valuable insights for refining the RME model to further enhance its effectiveness in future applications. Figure 4 illustrates the pretest and posttest performance of students in the experimental group across each mathematical thinking indicator.

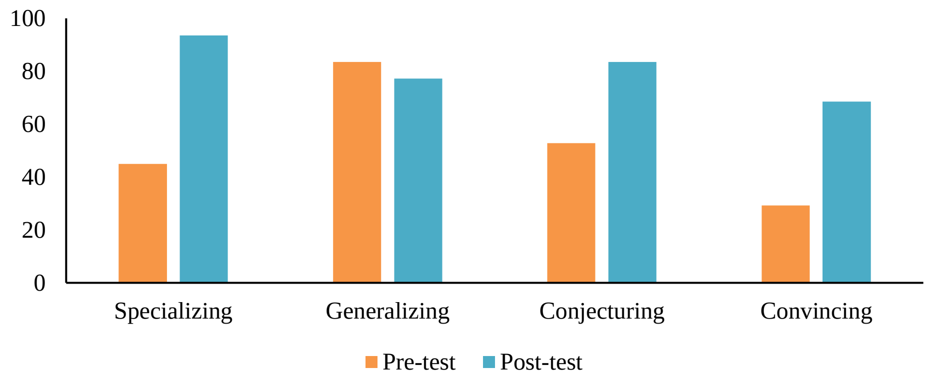

Figure 4. Increasing the achievement of each indicator of mathematical thinking ability

Aini et al. (2019) found that mathematical thinking skills improved due to the implementation of Android applications that facilitated learning. The mobile module enhanced mathematical thinking skills by capturing students' attention and encouraging active engagement in learning (Henry Suryo Bintoro et al., 2022b; Liu et al., 2018; R. Rahayu et al., 2019).

The application's integration into the learning process enabled students to understand the cultural associations embedded in ethnomathematics (Ajmain et al., 2020; Saputra et al., 2018). Additionally, teachers could use the ethnomathematics mobile module to instil national values, thereby fostering character development. The module motivated students to explore various learning resources and actively engage in learning activities, which contributed to better retention of information. Furthermore, Android applications supported long-term learning by serving as an interactive exercise tool that reinforced knowledge and improved learning outcomes. These applications provided students with flexible learning opportunities, allowing them to study anytime and anywhere (Pujiastuti et al., 2020; Siahaan et al., 2021; Yanti & Effendi, 2022).

The implementation of the ethnomathematics mobile module played a crucial role in enhancing mathematical thinking skills. This approach engaged students effectively and prevented monotonous learning experiences. The module's accessibility enabled students to utilize it regularly, regardless of time or location. Android-based applications also fostered motivation and created a dynamic, engaging learning environment (Liliarti & Kuswanto, 2018; Radita & Nurfauziah, 2022). Consequently, the integration of Android-based applications positively influenced students' learning outcomes.

▪ CONCLUSION

Based on the discussion and hypothesis test results, the researchers concluded that the RME approach, assisted by the ethnomathematics mobile module, effectively enhanced the mathematical thinking skills of seventh-grade students. The study yielded three key findings. First, a significant difference existed in the mathematical thinking skills of students taught using the RME approach assisted by the ethnomathematics mobile module compared to those taught through traditional lecturing. Second, students taught using the RME approach assisted by the ethnomathematics mobile module achieved an N-gain score of 0.59, categorized as moderate, indicating a notable improvement in mathematical thinking skills. Third, a statistically significant difference was observed in the enhancement of mathematical thinking skills between students instructed with the RME approach assisted by the ethnomathematics mobile module and those taught through the lecture method. This study focused exclusively on seventh-grade students' mathematical thinking skills in the context of data presentation. Ideally, the ethnomathematics mobile module should encompass all mathematical topics in the seventh-grade curriculum. The researchers recommend the integration of application-based media into mathematics instruction. To maximize accessibility, developers should ensure that the application is compatible with Android, iOS, and other operating systems, allowing seamless installation on students' devices.

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