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Enhancing Students' Problem-Solving Skills through Ethnomathematics-Based Geometry Learning with an Android Mobile Application

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Abstract:
Despite the growing integration of technology in mathematics education, research on mobile learning platforms embedding local cultural contexts—particularly ethnomathematics—remains limited at the junior secondary level in Indonesia. Mathematical problem-solving ability remains a persistent challenge among students, necessitating Android-based learning media as a more engaging instructional solution. This investigation examined the extent to which an Android-based interactive mobile learning (m-learning) platform, integrated with ethnomathematics derived from Pontianak's local culture. A quasi-experimental posttest-only control-group design was adopted for this purpose. From nine classes at SMP Negeri 2 Pontianak, 60 participants were selected via cluster random sampling—30 in the experimental group receiving m-learning instruction and 30 in the comparison group receiving instruction without m-learning. Assessment of mathematical problem-solving capacity was conducted through a descriptive test comprising three items structured around Polya's four-stage indicators, with empirically established validity coefficients ranging from 0.94 to 0.96 and a reliability coefficient of 0.78. Statistical examination involved a one-tailed independent samples t-test for group comparison, supplemented by Cohen's d for effect size quantification. Findings revealed that learners exposed to m-learning instruction demonstrated substantially superior mathematical problem-solving performance compared to their counterparts in the conventional group (mean = 84.67 vs 72.63; $p < 0.05$), with a large effect magnitude (Cohen's d = 1.3). These outcomes affirm that the ethnomathematics-embedded Android-based m-learning platform constitutes an efficacious and educationally meaningful intervention for cultivating students' mathematical problem-solving proficiency. Nevertheless, further research on a broader scale is warranted to enhance the generalizability of these findings, along with the incorporation of a pretest to more rigorously assess gains and establish stronger causal evidence of the intervention's effectiveness.

Keywords: Android, Ethnomathematics, M-Learning, Problem-Solving Abilities, Quasi-Experimental.

Introduction

Among the core competencies that students are expected to cultivate during mathematics instruction, the capacity to solve mathematical problems occupies a central and irreplaceable position (Amalina & Vidákovich, 2023; Nugraheni & Marsigit, 2021; Olivares et al., 2021). Mathematics education experts have long recognized that mere procedural fluency—the ability to execute algorithms and memorize formulas—is insufficient preparation for the demands students will face in academic, professional, and everyday contexts. What is required instead is a deeper form of mathematical thinking that equips learners to navigate unfamiliar, non-routine challenges through reasoned inquiry. Classified as a higher-order thinking skill (HOTS), mathematical problem-solving demands that learners engage in sophisticated cognitive operations—including analysis, synthesis, and critical evaluation—to generate well-reasoned solutions when confronted with complex or novel mathematical situations (Abdullah et al., 2019; Hodiyanto & Firdaus, 2020). This is not merely a skill for academic success; it carries direct relevance to real-world contexts, where individuals are routinely required to translate mathematical understanding into practical responses to everyday challenges.

The strategic importance of problem-solving competency is affirmed by its central positioning within major international mathematics education frameworks. Curricula across multiple countries, including Indonesia's national curriculum (Kurikulum Merdeka), explicitly situate problem-solving as one of the core learning targets (Kurikulum & Pendidikan, 2022), reflecting global consensus that mathematics education must transcend rote knowledge transmission and instead develop students' capacity to think flexibly and strategically. In this sense, cultivating problem-solving ability is not merely a pedagogical preference but a curricular imperative with broad developmental and societal implications.

Despite its recognized importance, empirical evidence consistently points to the relatively underdeveloped problem-solving abilities of Indonesian students (Hodiyanto, 2017; Hodiyanto et al., 2020; Mohamad Salam et al., 2024; Risnawati et al., 2018; Salemeh & Etchells, 2016; Wahyuni et al., 2025; Yani et al., 2021, 2022). Results from large-scale international assessments such as PISA and TIMSS have repeatedly highlighted the challenges Indonesian students face when dealing with non-routine mathematical tasks that require reasoning and problem-solving ability (Safrudiannur & Rott, 2019). Students still experience significant difficulties in solving mathematical problems, especially in geometric materials such as prisms and pyramids (Hodiyanto et al., 2026). These difficulties are not merely superficial gaps in knowledge but reflect deeper structural weaknesses in how problem-solving competencies are cultivated within the learning environment.

One factor that has been identified as significantly contributing to these persistent weaknesses is the suboptimal quality of instructional media employed in mathematics classrooms, particularly the underutilization of technology-based resources capable of offering dynamic, interactive learning experiences (Choirudin et al., 2025). Among such technologies, Android-powered mobile learning (m-learning) platforms have attracted growing scholarly attention for their pedagogical potential, yet their systematic integration into mathematics instruction in Indonesian schools remains limited (Murtiyasa et al., 2020). This gap represents a missed opportunity, given that the penetration of Android-based smartphones among the adolescent population in Indonesia is exceptionally high, making mobile learning not only pedagogically promising but also practically accessible.

Mobile learning—defined broadly as any form of educational engagement mediated via portable digital devices—represents a pedagogical innovation that transcends the spatial and temporal constraints of traditional classroom instruction, enabling knowledge acquisition at any time and in virtually any location (Naveed et al., 2023; Qazi et al., 2024). Several characteristics distinguish m-learning from conventional instruction in ways particularly relevant to problem-solving development. First, the interactive and dynamic character of well-designed m-learning applications enables students to engage actively with content through exploration, simulation, and feedback rather than passively receiving information. Second, the self-paced nature of mobile learning accommodates the individual variability in learning speed, understanding, and readiness that is invariably present in any classroom. Third, the portability of mobile devices allows learners to revisit and consolidate understanding outside formal class hours, extending meaningful engagement with mathematical ideas into everyday life. These features collectively create conditions particularly conducive to the kind of sustained, reflective practice that effective problem-solving development requires.

However, the potential of m-learning to promote meaningful mathematical understanding is substantially amplified when it is embedded within a culturally responsive pedagogical framework—specifically, an ethnomathematics approach (Abdulrahim & Orosco, 2020; Gbormittah et al., 2025; Rosa & Orey, 2016; Villarin et al., 2024). Ethnomathematics, as a field, is premised on the recognition that mathematical knowledge does not exist in a cultural vacuum but is embedded in and expressed through the practices, artifacts, and traditions of human communities. When instructional materials draw on the cultural heritage and lived experiences of students as legitimate mathematical contexts, two mutually reinforcing benefits emerge. First, students' cognitive engagement intensifies because the problem context is familiar, meaningful, and personally relevant—reducing the cognitive overhead associated with making sense of an artificial or abstract scenario. Second, students' affective engagement and sense of mathematical identity are strengthened, as they come to see their own cultural backgrounds as valid sources of mathematical knowledge rather than irrelevant to formal schooling. These dimensions collectively enhance both the accessibility and depth of mathematical learning.

The combination of m-learning and ethnomathematics is therefore not merely additive but potentially transformative. When the interactivity and accessibility of mobile technology are paired with the contextual richness and cultural resonance of ethnomathematics, the resulting instructional environment addresses simultaneously the motivational, cognitive, and contextual dimensions of effective problem-solving development. Building on this rationale, Hodiyanto et al. (2026) previously designed and developed an Android-based interactive m-learning application for prism and pyramid instruction at SMP Negeri 2 Pontianak, deliberately embedding ethnomathematical elements drawn from Pontianak's cultural heritage. The platform incorporates locally recognized objects—ketupat (a pyramid-shaped traditional food), patlau (a prism-shaped traditional food), and pengkang (a food that assumes both prism and pyramid forms)—as authentic contextual anchors for mathematical inquiry. Evaluation outcomes from this development study confirmed that the resulting application exhibited very high levels of content validity, media quality, practical usability for both educators and students, and instructional effectiveness as measured through pre-to-post performance comparisons. Although this study has produced valid, practical, and effective media, it has limitations in its research design. The development research using the 4-D model employed a one-group pretest-posttest design without a control group, so it has not been possible to empirically confirm whether the increase in student abilities was truly caused by m-learning media or by other factors, such as learning effects. To overcome this limitation, further research is needed with a quasi-experimental design involving a control group to compare the effectiveness of m-learning media with learning without m-learning media.

Several previous studies have tested the effectiveness of m-learning in mathematics using quasi-experimental designs. Fabian et al. (2018) discovered that the integration of mobile technology in mathematics education markedly enhanced students' performance and their perceptions of the subject. Fahmi and Qohar (2023) also reported that Android-based m-learning applications effectively improve students' mathematics learning outcomes. However, these studies have not integrated ethnomathematics as a learning context. Research that integrates ethnomathematics into digital learning media, such as that conducted by Andang et al. (2025), shows promising results in improving problem-solving skills but uses modular media, not Android-based m-learning. Research conducted by Novitasari & Walid (2022) also developed Android-based learning media using Articulate Storyline 3 software on linear programming material through a research and development approach. Meanwhile, this study offers several novelties that distinguish it from the aforementioned research, namely, the learning media were designed using Smart Apps Creator (SAC), the approach employed is an experimental method, the ethnomathematics content integrated is drawn from the local wisdom of Pontianak culture, and the material presented focuses on cubes and rectangular prisms. No study to date has combined Android-based m-learning with ethnomathematics from Pontianak's local culture within a quasi-experimental design.

Based on this background, this study aims to test the effectiveness of Android-based interactive m-learning media integrated with ethnomathematics in improving students' mathematical problem-solving abilities with prism and pyramid materials. Specifically, this study has two objectives: (1) to compare the mathematical problem-solving abilities between students taught using ethnomathematics-integrated m-learning media with students taught without using m-learning media, and (2) to measure the effectiveness (effect size) of ethnomathematics-integrated m-learning media in improving students' mathematical problem-solving abilities. The findings are intended to furnish more robust empirical grounding for the adoption of culturally contextualized mobile learning technologies within mathematics education and to offer actionable guidance for practitioners and policymakers seeking evidence-based approaches to improving mathematical problem-solving instruction.

Research Methods

A quasi-experimental design with a posttest-only control group configuration was selected for this study. This methodological choice was driven by the study's central aim of comparing problem-solving capacity between the experimental group, taught using ethnomathematics-integrated m-learning media, and the control group, taught without m-learning media. The research design is presented in Table 1.

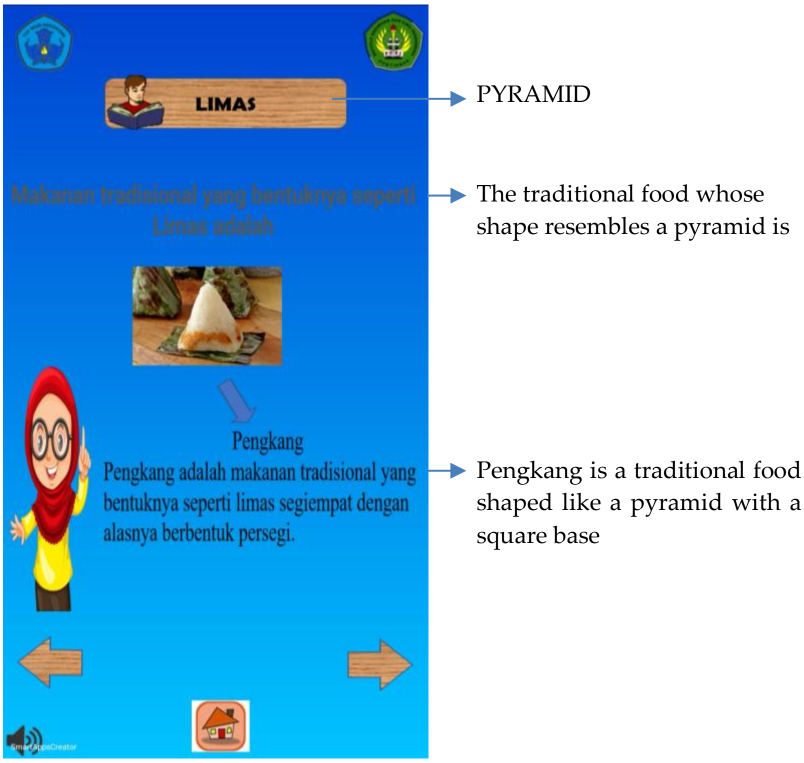
Table 1. Posttest-Only Control Group Research Design

Group	Treatment	Posttest
Experiment	X	O_1
Control	-	O_2

Description: X = Learning using ethnomathematics integrated m-learning media; O_1 = Posttest of the experimental group; O_2 = Posttest of the control group

The study was conducted in the odd semester of the 2025/2026 academic year at SMP Negeri 2 Pontianak, West Kalimantan. Learning in both groups was conducted in 3 meetings with a time allocation of 2 x 40 minutes per meeting on the material of prisms and pyramids. The study population consisted of all eighth-grade students at SMP Negeri 2 Pontianak, comprising nine classes. Both classes were taught by the same teacher. The research sample was selected through a cluster random sampling technique, namely by randomly selecting 2 classes from 9 existing classes. The selected classes were then randomly assigned to an experimental group (30 students) taught using m-learning media integrated with ethnomathematics and a control group (30 students) taught without m-learning media. The total research sample was 60 students.

The measurement instrument consisted of a constructed-response test encompassing three items, each designed to elicit responses aligned with the four sequential stages of Polya's (2014) problem-solving framework: (1) understanding the problem, (2) making a plan, (3) carrying out the plan, and (4) looking back. The research instrument comprises three items, as these are considered representative in measuring the concept being taught. This instrument was originally developed and validated within Hodiyanto et al.'s (2026) development research. Empirical validation procedures confirmed robust psychometric properties, with item-level validity coefficients spanning from 0.94 to 0.96 and an overall reliability index of 0.78, attesting to the instrument's measurement consistency and precision. The m-learning application presents pyramid material through the context of pengkang, a traditional food from Pontianak whose shape resembles a quadrilateral pyramid with a square base, as illustrated in Picture 1. This ethnomathematical contextualization allows students to connect abstract geometric concepts with culturally familiar objects from their everyday environment.



Picture 1. Sample Screen of the M-Learning

Data were subjected to both descriptive and inferential analytical procedures. Descriptive summaries encompassed computation of group means, standard deviations, and score ranges. Prior to inferential testing, distributional assumptions were verified through the Shapiro-Wilk normality test and Levene's test of variance homogeneity. Hypothesis evaluation was then conducted using a one-tailed independent-samples t-test to determine whether the m-learning group's problem-solving scores significantly surpassed those of the comparison group. All computations were executed using SPSS statistical software. Additionally, Cohen's d was computed to assess the practical magnitude of the observed group difference, applying the formula:

$$d = (M_1 - M_2) / SD$$

where M_1 represents the experimental group's mean, M_2 denotes the control group's mean, and SD refers to the pooled standard deviation. Effect size interpretation followed Cohen's conventional benchmarks: values of 0.2, 0.5, and 0.8 correspond to small, medium, and large effect magnitudes, respectively (Lakens, 2013).

Results and Discussions

Research result

This study yielded data on students' mathematical problem-solving abilities from two groups: the experimental group, taught using ethnomathematics-integrated m-learning media, and the control group, taught without m-learning media. A description of the research data is presented in Table 2.

Table 2. Descriptive Statistics of Mathematical Problem-Solving Ability

Group	N	Mean	Standard Deviation	Min	Max
Experiment (M-Learning)	30	84.67	8.94	67	100
Control (Without M-Learning)	30	72.63	9.54	58	89

Based on Table 2, the experimental group's average mathematical problem-solving ability (M = 84.67; SD = 8.94) is higher than the control group's (M = 72.63; SD = 9.54), with an average difference of 12.04 points. The minimum and maximum scores of the experimental group (67-100) also span a wider range than those of the control group (58-89). These data provide an initial indication that the experimental group has better mathematical problem-solving ability than the control group. Before conducting the hypothesis test, a prerequisite analysis was conducted, including normality and homogeneity tests. The Shapiro-Wilk normality test was used to assess whether the mathematical problem-solving ability data in both groups were normally distributed. The results of the normality test are presented in Table 3.

Table 3. Results of the Shapiro-Wilk Normality Test

Group	Statistics	df	Sig.
Experiment	0.963	30	0.374

Control	0.935	30	0.068

The results of the normality test in Table 3 show that The significance values yielded by the Shapiro-Wilk test were 0.374 and 0.068 for the experimental and control groups, respectively. Given that both values exceed the α = 0.05 threshold, the null hypothesis of normality was retained for each group, confirming that the parametric test assumption of normally distributed data was satisfied. Variance homogeneity was subsequently assessed via Levene's test, with findings presented in Table 4.

Table 4. Results of Levene's Test of Homogeneity

Levene Statistics	df1	df2	Sig.
0.173	1	58	0.679

The results of the homogeneity test in Table 4 indicate that Levene's test produced a significance value of 0.679, surpassing the α = 0.05 cutoff, indicating that variances across the two groups were statistically equivalent. With both normality and homogeneity assumptions verified, the independent-samples t-test was deemed appropriate. A one-tailed variant was applied to evaluate whether m-learning participants outperformed non-m-learning participants in problem-solving ability. Hypothesis testing results are summarized in Table 5.

Table 5. Results of the One-Tailed Independent Samples t-Test

t	df	Sig. (2-tailed)	Sig. (1-tailed)	Cohen's d
5.12	58	0,000	0,000	1.3

The t-test yielded a statistic of 5.12 (df = 58) with a one-tailed p-value = $0.000 < 0.05$. Consequently, H_0 was rejected in favor of H_1, establishing that the experimental group's problem-solving proficiency was significantly superior to that of the control group. Furthermore, the computed Cohen's d value of 1.3—classified within the large effect category—underscores the magnitude of the instructional benefit conferred by the ethnomathematics-integrated m-learning media.

Discussion

The study found that students taught using ethnomathematics-integrated m-learning media demonstrated significantly better mathematical problem-solving abilities than those taught without m-learning media. This finding is consistent with previous studies demonstrating the effectiveness of m-learning in improving mathematics learning outcomes (Engelbrecht & Borba, 2024; Fabian et al., 2018; Fahmi & Qohar, 2023; Poçan et al., 2023; Rakes et al., 2020) and research showing that ethnomathematics integration can improve students' mathematical problem-solving abilities (Andang et al., 2025; Novitasari & Walid, 2022). This research strengthens the empirical evidence that combining mobile learning technology with local cultural context can positively contribute to mathematics learning. The results of a recent meta-analysis reinforce these findings, with Güler et al. (2022) reporting a medium effect size (g = 0.476) for mobile learning in mathematics, while Sung et al. (2016) found a consistent positive effect (d = 0.22) when mobile devices were integrated into learning. Rakes et al. (2020), through a systematic review and meta-analysis, found that mathematics educational technology produces a modest but significant effect size, especially when combined with appropriate pedagogy and adequate implementation duration.

The integration of Pontianak's cultural ethnomathematics, including ketupat, patlau, and pengkang, significantly contributes to the success of m-learning media in improving students' mathematical problem-solving abilities. These local cultural objects serve as a bridge between abstract formal mathematical concepts and students' concrete experiences in everyday life (Rosa & Orey, 2016; Villarin et al., 2024). When students are faced with problem-solving tasks that use the context of ketupat, patlau, or pengkang, they more easily understand the problem situation because these objects are already familiar to them. This reduces students' cognitive burden in understanding the problem context, allowing them to focus more on the problem-solving process itself. These results also align with previous research showing that ethnomathematics-based learning media can improve students' problem-solving abilities (Günay & Takunyaci, 2023; Lubis et al., 2021; Nur et al., 2020; Pratama & Afriani, 2025; Sumaji et al., 2025).

The influence of m-learning media in improving mathematical problem-solving skills can be explained through several mechanisms. First, the interactive features in m-learning media enable students to actively engage in the learning process through independent exploration, simulations, and practice problems that can be accessed repeatedly as needed (Qazi et al., 2024). Second, 3D visualizations of geometric objects such as prisms and pyramids in media help students develop better spatial understanding, a crucial aspect of solving geometry problems. Third, m-learning media facilitate student-centered learning, allowing students to learn at their own pace, review material they do not understand, and work on exercises at their own level.

The m-learning media developed by Hodiyanto et al. (2026) also provides a structured guiding framework to navigate students through the problem-solving stages outlined by Polya (2014): understanding the problem, planning a solution, implementing the plan, and reviewing the results. This scaffolding helps students develop systematic thinking habits in solving mathematical problems. In the control group that did not use m-learning media, students tended to solve problems procedurally without a profound understanding of the problem-solving process, so their abilities did not develop optimally.

Cohen's d value of 1.3, which falls within the large effect category, indicates that the ethnomathematics-integrated m-learning media not only provides a statistically significant difference but also has a substantial practical impact. This means that implementing this media in other classes is expected to provide real and meaningful improvements in problem-solving skills. This finding is important for education practitioners and policymakers considering adopting technology-based learning media integrated with local wisdom.

This study's findings have numerous practical ramifications. Mathematics teachers can utilize ethnomathematics-integrated m-learning media as an effective alternative learning medium to enhance students' mathematical problem-solving skills, especially in geometry. For schools, the results of this study can serve as a basis for providing adequate technological infrastructure and encouraging teachers to develop and use technology-based learning media. For learning media developers, this study demonstrates the importance of integrating local cultural contexts into digital learning media to make learning more meaningful and relevant for students.

Conclusions and Suggestions

Based on the research results and discussion, it can be concluded that the mathematical problem-solving ability of students taught using Android-based interactive m-learning media integrated with Pontianak cultural ethnomathematics is better than that of students taught without using m-learning media. The ethnomathematics-integrated m-learning media that integrates local cultural objects such as ketupat, patlau, and pengkang has been effective in improving students' mathematical problem-solving ability with prism and pyramid materials, with a large effect size. This shows that m-learning media not only provides statistically significant differences but also has a substantial practical impact on mathematics learning.

Mathematics teachers are advised to use Android-based interactive m-learning media integrated with ethnomathematics as an alternative learning medium to improve students' mathematical problem-solving skills, particularly in geometry. Teachers can adapt the developed media by integrating local cultural objects familiar to students in their respective regions. Furthermore, teachers need to guide students in using m-learning media to ensure optimal learning and encourage them to use the media's interactive features for independent exploration and practice.

Future researchers are advised to undertake several actions. First, conduct research with a larger and more diverse sample to test the generalizability of the media's effectiveness across various school contexts. Second, conduct longitudinal research over a longer period to observe the long-term impact of m-learning media use on students' mathematical problem-solving abilities. Third, expand the learning materials beyond prisms and pyramids to include other mathematical topics such as statistics, probability, or algebra. Fourth, develop additional features within the media, such as a learning progress-tracking system, online discussion forums, and gamification elements, to increase student engagement. Fifth, incorporate a pre-test at the beginning of the study to measure students' initial knowledge and abilities, thereby enabling a more accurate assessment of the media's actual impact on learning outcomes.

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