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MINANG CULTURE-BASED LEARNING TRAJECTORY IN IMPROVING MATHEMATICAL COMMUNICATION SKILLS OF SMA NEGERI 3 PADANG STUDENTS

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Abstrak

Penelitian ini bertujuan untuk mengimplementasikan alur pembelajaran berbasis budaya Minangkabau dan untuk meningkatkan kemampuan komunikasi matematika siswa di SMA Negeri 3 Padang. Penelitian ini menggunakan pendekatan penelitian desain dengan tiga fase (desain awal, eksperimen pengajaran, dan analisis retrospektif), penelitian ini melibatkan 36 siswa untuk kelas eksperimen dan 8 siswa untuk kelas awal (studi pendahuluan). Jalur pembelajaran tersebut mengintegrasikan konteks budaya Minangkabau seperti arsitektur rumah tradisional, tekstil tradisional, dan sistem pasar ke dalam kegiatan pembelajaran matematika. Alur pembelajaran diimplementasikan pada topik geometri transformasional (translasi, refleksi, rotasi, dan dilatasi). Hasil penelitian menunjukkan peningkatan yang signifikan pada kemampuan komunikasi matematika siswa, dengan nilai rata-rata meningkat dari 62,3 (pre-test) menjadi 84,7 (post-test). Siswa menunjukkan peningkatan kemampuan dalam mengekspresikan ide matematika secara lisan dan tertulis, menggunakan representasi matematika, dan menafsirkan pernyataan matematika. Jalur pembelajaran berbasis budaya terbukti efektif dalam membuat matematika lebih bermakna dan relevan dengan kehidupan sehari-hari siswa.

Kata kunci: Budaya Minangkabau; Etnomatematika; Komunikasi Matematika; Lintasan Pembelajaran; Riset Desain

Abstract

This study aimed to implement a Minangkabau culture-based learning pathway and to improve students' mathematical communication skills at SMA Negeri 3 Padang. This study uses a design research approach with three phases (preliminary design, teaching experiment, and retrospective analysis), the study involved 36 students in the main teaching experiment after a pilot study involving 8 students. The learning trajectory integrated Minangkabau cultural contexts such as traditional house architecture, traditional textiles, and market systems into mathematics learning activities. The learning trajectory was implemented on transformational geometry topics (translation, reflection, rotation, and dilation). The results showed a significant improvement in students' mathematical communication skills, with the average score increasing from 62.3 (pre-test) to 84.7 (post-test). Students demonstrated improved abilities in expressing mathematical ideas orally and in writing, using mathematical representations, and interpreting mathematical statements. The culture-based learning trajectory proved effective in making mathematics more meaningful and relevant to students' daily lives.

Keywords: Design Research; Ethnomathematics; Learning Trajectory; Mathematical Communication; Minangkabau Culture

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INTRODUCTION

Mathematical communication skills are one of the essential competencies that students must master in mathematics learning. The National Council of Teachers of Mathematics emphasizes that mathematical communication enables students to organize and consolidate their mathematical thinking, express mathematical ideas coherently and clearly to others, and analyze and evaluate others' mathematical thinking and strategies.

Mathematical communication skills are students' abilities to express, explain, describe, listen, ask questions, and collaborate, thus leading students to a deep understanding of mathematics (NCTM, 2020). According to (Greenes, C., & Schulman, L, 2021), mathematical communication includes the ability to: (1) Express mathematical ideas through oral, written, and demonstration; (2) Understand, interpret, and evaluate mathematical ideas presented in oral, written, or visual form; (3) Use mathematical vocabulary, notation, and structures to represent ideas, describe relationships, and model situations.

Mathematical communication ability indicators according to (Kadir, K., & Masi, L, 2023) include: (1) The ability to express mathematical ideas orally, in writing, and to describe them visually; (2) The ability to interpret and evaluate mathematical ideas both orally and in other visual forms; (3) The ability to use mathematical terms, notations and structures to present ideas, describe relationships and situation models.

However, initial observations at SMA Negeri 3 Padang showed that students' mathematical communication skills were still low. Of the 36 eleventh-grade students observed, only 38% were able to explain mathematical concepts well, 42% were able to create accurate mathematical representations, and 35% were able to interpret mathematical statements correctly. Furthermore, observations indicate that the local cultural context has not been utilized as a source for learning mathematics even though SMA Negeri 3 Padang has a school vision that emphasizes character building, preserving regional culture, and a love of Minangkabau culture. This condition indicates a gap between the school's vision and the ongoing mathematics learning practices. This is in line with the findings of (Rahmawati, FP, & Zanthy, LS, 2019) who stated that the mathematical communication skills of high school students in Indonesia are still in the low to moderate category.

One factor contributing to low mathematical communication skills is mathematics learning, which remains abstract and lacking meaning for students (Wijaya, 2022). Learning that is not connected to students' life contexts makes it difficult for them to understand and communicate mathematical concepts.

The ethnomathematics approach offers a solution by integrating local culture into mathematics learning (D'Ambrosio, 2020). Minangkabau culture, rich in mathematical concepts in the architecture of traditional houses (rumah gadang), traditional textile motifs (songket and embroidery), traditional measurement systems, and the market economy, can provide a meaningful context for mathematics learning. Ethnomathematics is the study of mathematical practices embedded in culture (D'Ambrosio, 2020). The ethnomathematical approach recognizes that each culture has unique ways of understanding, using, and developing mathematics (Rosa, M., & Orey, D.C, 2021).

Minangkabau culture is rich in mathematical concepts that can be used as a learning context. The architecture of the traditional house (rumah gadang) incorporates complex geometric concepts, including symmetry, the golden ratio, and a buffalo horn-shaped roof structure that incorporates concepts of angles, triangles, and geometric transformations (Fauzi, A., & Suryadi, D, 2022). Minangkabau songket and embroidery feature regular geometric patterns, reflecting concepts of symmetry, translation, rotation, and reflection (Arisetyawan, 2020). Traditional Minangkabau measurement systems, such as the cupak, gantang, and hasta, incorporate concepts of measurement and unit conversion (Wulandari, 2021). The traditional Minangkabau market economy, with its bargaining system and profit-loss calculations, incorporates concepts of arithmetic, percentages, and algebra (Hasanah, U., & Surya, E, 2023). Previous studies mainly explored geometric concepts in Rumah Gadang architecture, songket motifs, and traditional economic systems. However, studies focusing on the development of a comprehensive learning trajectory integrating multiple Minangkabau cultural contexts to improve mathematical communication skills remain limited.

A Minangkabau culture-based learning trajectory is designed as a series of structured and continuous learning activities, where each activity is based on an understanding of how students learn mathematics in their cultural context (Simon, 2020). This study developed a learning trajectory that integrates Minangkabau culture to improve students' mathematical communication skills.

A learning trajectory is a description of a student's thinking and learning in a mathematical domain, including learning goals, learning activities designed to help students achieve those goals, and hypotheses about the student's learning process (Simon, 2020); (Clements, D.H., & Sarama, J, 2022).

According to (Daro, P., Mosher, F.A., & Corcoran, T, 2021), the components of a learning trajectory consist of: (1) Mathematics learning goals; (2) Student understanding development (developmental progression); and (3) Instructional activities. Learning trajectories assist teachers in designing learning that is appropriate to students' cognitive developmental levels and provides appropriate scaffolding to help students achieve higher conceptual understanding (Lobato, 2023).

Several studies have demonstrated the effectiveness of culturally-based learning. Research by (Utami, 2022) showed that Javanese culture-based mathematics learning improved students' conceptual understanding by 35%. (Sari, N., & Valentino, E, 2021) found that integrating Malay culture into mathematics learning improved student motivation and learning outcomes.

Specifically regarding Minangkabau culture, research by (Afriyani, D., & Sari, N, 2023) shows that using the traditional house context in geometry learning improves students' spatial abilities. However, no research has specifically developed a Minangkabau-based learning trajectory to improve mathematical communication skills, making this research important. In general, previous research has shown that the use of ethnomathematics from various cultures, particularly Minangkabau culture, can improve several students' mathematical abilities. However, this research is still limited to specific cultural objects and specific mathematical abilities. Furthermore, there is still little research developing Minangkabau ethnomathematics-based learning tools integrated with modern learning approaches to improve more complex mathematical abilities, such as problem-solving, critical thinking, or mathematical literacy. Therefore, research that develops and implements Minangkabau ethnomathematics-based learning tools in specific school contexts is important.

Based on the results of initial observations at SMA Negeri 3 Padang, students' mathematical communication skills are still relatively low and mathematics learning has not optimally integrated the local cultural context that is close to students' lives. Meanwhile, previous research has focused more on improving spatial abilities, conceptual understanding, and learning motivation through ethnomathematics, while the development of Minangkabau culture-based learning trajectories to improve mathematical communication skills has not been widely carried out. Therefore, this study aims to develop and implement Minangkabau culture-based learning trajectories on geometric transformation material and examine their effectiveness in improving students' mathematical communication skills at SMA Negeri 3 Padang.

METHOD

This study uses a design research approach with the (Gravemeijer, K., & Cobb, P, 2019) model which consists of three phases: (1) Preliminary Design - Developing an initial design of the learning trajectory based on literature analysis, curriculum analysis, and analysis of the Minangkabau cultural context; (2) Teaching Experiment - Implementing the learning trajectory by observing and documenting the learning process; (3) Retrospective Analysis - Data analysis to evaluate and revise the learning trajectory. Although this study utilized all stages of design research, this article specifically reports the results of the Teaching Experiment phase and evaluates the effectiveness of the developed learning trajectory. The results of the Preliminary Design and Retrospective Analysis are presented briefly as context for the development.

Figure 1 illustrates the position of learning trajectory development within the design research framework. The Preliminary Design phase generated the initial HLT, which was tested and refined during the Teaching Experiment phase. Findings from classroom implementation were subsequently analyzed during the Retrospective Analysis phase to evaluate and improve the learning trajectory. Here is a suggested explanatory paragraph and a positioning chart you can include in your paper:

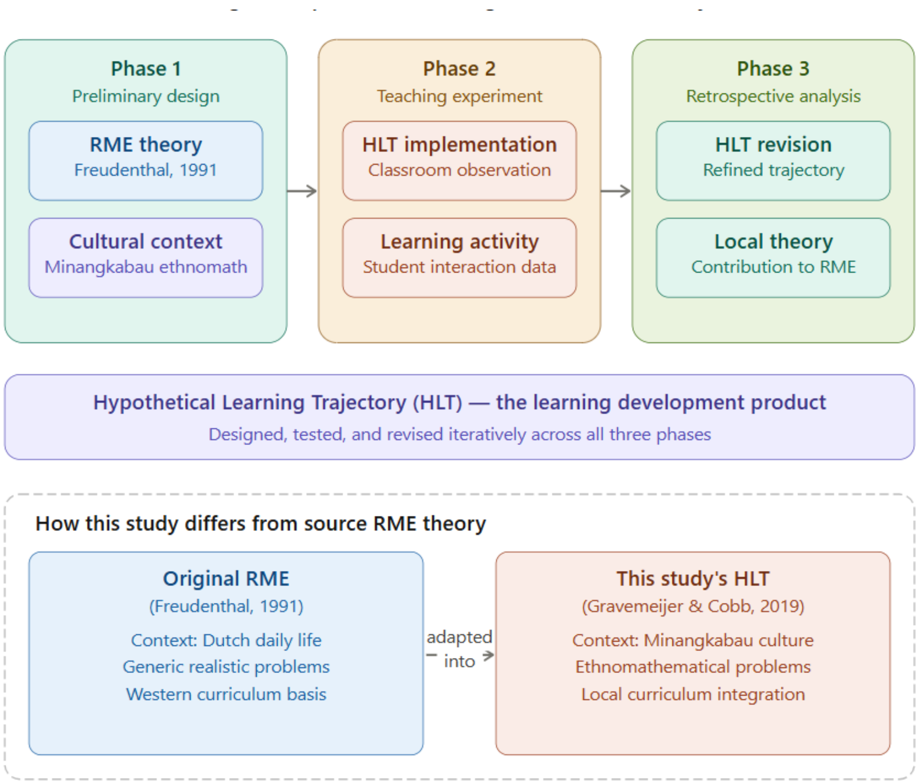

Figure 1. Position of learning development within design research

The research subjects were 36 grade XI MIPA 2 students of SMA Negeri 3 Padang in the 2025/2026 academic year. Subject selection was based on the consideration that grade XI students already have sufficient prerequisite knowledge for the material being taught and that the school has students with a strong Minangkabau cultural background.

Instruments used in this study:

1. Mathematical Communication Ability Test: Pre-test and post-test consisting of 5 descriptive questions that measure mathematical communication indicators.
2. Observation Sheet: To observe the learning process and student interactions.
3. Interview Guidelines: To explore students' understanding of mathematical concepts in a cultural context.
4. Documentation: In the form of photos, learning videos, and student work results.

Before use, the mathematical communication test instrument and observation sheet were validated by three mathematics education experts. Aiken's V values for each item ranged from 0.84 to 0.96, indicating excellent content validity. The instrument was piloted on 30 students outside the research sample and yielded a Cronbach's Alpha reliability coefficient of 0.87 for the mathematical communication test and 0.85 for the observation sheet.

Phase 1: Preliminary Design (2 weeks) - Curriculum analysis, identification of mathematical concepts in Minangkabau culture, designing Hypothetical Learning Trajectory (HLT), and instrument validation. Phase 2: Teaching Experiment (6 weeks) - Implementation of pre-test, implementation of learning trajectory (12 meetings @90 minutes), observation and documentation, and implementation of post-test. Phase 3: Retrospective Analysis (2 weeks) - Quantitative and qualitative data analysis, data triangulation, and revision of learning trajectories.

A pilot experiment involving eight students tested the activity's feasibility, the clarity of the worksheets, and the cultural context appropriateness of the worksheets. The pilot results were used to revise several worksheet instructions and the activity's time allocation. After the revisions, the learning trajectory was implemented in a main teaching experiment involving all 36 students of grade XI MIPA 2.

Quantitative data analysis used the Shapiro-Wilk normality test, Levene's homogeneity test, paired sample t-test to see the difference between pre-test and post-test, and N-Gain calculation to measure the increase in ability.

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

N-Gain categories: > 0.7 (High), 0.3-0.7 (Medium), < 0.3 (Low). Qualitative data analysis includes data reduction from observations and interviews, data display in tabular and narrative form, verification and drawing conclusions, and data triangulation for the validity of findings.

RESULT AND DISCUSSION

The preliminary design phase involved three interconnected activities. First, a comprehensive literature review was conducted to identify relevant mathematical concepts, learning theories, and ethnomathematical resources related to Minang culture. Second, an exploratory field study was conducted, involving observations and informal interviews with Minang cultural practitioners, traditional weavers, and local community members to document the mathematical structures embedded in cultural artifacts and practices. Third, the initial HLT was developed, specifying: (a) the mathematical learning goals related to mathematical communication skills; (b) a sequence of five culturally situated learning activities; and (c) hypothetical descriptions of students' anticipated mathematical thinking at each stage.

The mathematical content addressed in the HLT encompassed transformation geometry (translation, reflection, rotation, and dilation), with mathematical communication skills targeted across three dimensions: (1) written mathematical communication using precise mathematical language in written explanations; (2) symbolic representation translating between visual, verbal, and algebraic representations; and (3) visual-graphical communication—constructing and interpreting geometric diagrams and patterns.

The teaching experiment was conducted over twelve meetings (90 minutes each). During this phase, the researcher functioned as a participant observer while the classroom teacher implemented the learning activities. The teaching experiment proceeded in two cycles: a pilot cycle with a small group of 8 students (not included in the main sample) followed by a main cycle with the full class of 36 students.

Each learning session was video-recorded, and field notes were maintained by the researcher. Student worksheets (*Lembar Kerja Peserta Didik*/LKPD) were designed to elicit and document students' mathematical reasoning and communication. The LKPD tasks were structured around authentic Minang cultural artifacts, requiring students to observe, describe, represent, and analyze mathematical structures. Brief semi-structured interviews were conducted with selected students after each session to probe their mathematical thinking.

Retrospective analysis was conducted by systematically comparing the implemented learning trajectory with the original HLT. The analysis followed a grounded theory approach (Strauss & Corbin, 1998), involving open coding of observational data, video transcripts, and student work samples, followed by focused coding and the identification of emergent themes related to students' mathematical communication development.

Quantitative data from pre-test and post-test instruments were analyzed using descriptive statistics and the normalized gain (N-gain) formula proposed by Hake (1998): N-gain = (post-test score − pre-test score) / (maximum score − pre-test score). N-gain values were interpreted as follows: N-gain ≥ 0.70 = high; $0.30 \leq$ N-gain < 0.70 = medium; N-gain < 0.30 = low.

The learning trajectory developed consists of 6 interrelated learning activities, each integrating the Minangkabau cultural context with specific mathematical concepts.

Activity 1: Exploring the Geometry of Rumah Gadang

Students identify and communicate the concepts of symmetry, angles, and proportion in traditional house architecture. They examine photographs/models of traditional houses, identify geometric shapes, measure roof angles, calculate height-to-width ratios, and then present their findings using diagrams and mathematical explanations.

Activity 2: Patterns and Symmetry in Minangkabau Songket

Students communicate the concept of geometric transformations (translation, rotation, reflection) through the analysis of songket motifs. They analyze songket patterns, identify the types of geometric transformations, redraw the patterns using Cartesian coordinates, and explain the patterns using mathematical notation.

Activity 3: Traditional Measurement Systems in Trade

Students communicate the concepts of unit conversion and proportion through traditional measurement systems (cupak, gantang, kulak, hasta). They simulate traditional market trading, convert between units of measurement, solve contextual problems, and present calculation strategies.

Activity 4: Mathematics in the Minangkabau Market Economic System

Students communicate social arithmetic concepts (profit and loss, discounts, interest) in the context of a traditional market. They role-play as sellers and buyers, calculate prices, profit and loss, and discount percentages, then create a written report with mathematical justification.

Activity 5: Statistical Analysis of Minangkabau Cultural Data

Students communicate data in the form of tables, diagrams, and statistical interpretations using data on visitors to traditional houses, songket craft production, and commodity prices in the market. They collect cultural data, create visual representations, calculate measures of central tendency, and present data analyses.

Activity 6: Integration Project - Designing a Miniature Rumah Gadang

Students integrate and communicate various mathematical concepts in one comprehensive project. They design a scaled blueprint for a traditional house, calculate area, material volume, and estimate costs, and create a project presentation with complete mathematical justification.

The learning trajectory was implemented in 12 meetings (each 90 minutes) with systematic steps. Learning began with a virtual visit to the Rumah Gadang Baanjuang Museum. Students demonstrated high enthusiasm and active participation in every activity.

Observations showed an increase in the frequency and quality of group discussions. In the initial meeting, students were hesitant and often used colloquial language. By the final meeting, they were more confident in using appropriate mathematical terms. Quote from a student interview: "I just realized that my grandmother's traditional house has many mathematical concepts. The gonjong roof actually uses precise angles, not random ones."

The project activity of designing a miniature traditional house was the culmination of the learning process. Each group successfully designed a 1:50 scale blueprint, accurately calculating the area, material volume, and cost estimates. The group presentations demonstrated strong oral communication skills, with the use of appropriate mathematical terminology and the ability to answer questions with logical mathematical arguments.

The pre-test and post-test results of students' mathematical communication skills showed significant improvement. Table 1 shows descriptive statistics of the mathematical communication skills scores.

Table 1. Descriptive Statistics of Mathematical Communication Ability Scores

Statistics	Pre-test	Post-test
N	36	36
Mean	62.3	84.7
Median	64.0	86.0
Standard Deviation	8.42	6.15
Minimum	45	70
Maximum	78	96

Table 1 shows an increase in the average score from 62.3 (medium category) to 84.7 (high category), with an increase of 22.4 points or 36%.

Table 2. Frequency Distribution of Mathematical Communication Ability Categories

Category	Score Range	Pre-test	Post-test
Very high	85-100	0 (0%)	20 (55.6%)
Tall	70-84	12 (33.3%)	16 (44.4%)
Currently	55-69	20 (55.6%)	0 (0%)
Low	40-54	4 (11.1%)	0 (0%)
Very Low	0-39	0 (0%)	0 (0%)

Table 2 shows a significant shift in the distribution. In the pre-test, no students were in the very high category, but in the post-test, 55.6% of students were in that category. The results of the Shapiro-Wilk normality test showed that the data were normally distributed (pre-test: $p = 0.156$; post-test: $p = 0.213$). The results of the paired sample t-test showed a significant difference ($t = 15.847$; $p = 0.000 < 0.05$) between the pre-test and post-test scores. The N-Gain calculation of 0.59 indicated an increase in mathematical communication skills in the moderate category.

Table 3. Improvement per Indicator of Mathematical Communication Ability

Indicator	Pre-test	Post-test	Gain	N-Gain	Category
Expressing mathematical ideas in writing	58.3	82.5	24.2	0.58	Currently
Expressing mathematical ideas orally	60.8	85.6	24.8	0.63	Currently
Using mathematical representation	64.2	86.1	21.9	0.61	Currently
Interpreting mathematical statements	63.5	84.4	20.9	0.57	Currently
Using mathematical terms and notation	64.7	85.0	20.3	0.58	Currently

Table 3 shows that all indicators experienced an increase in the moderate category, with the highest increase in the ability to express mathematical ideas orally (N-Gain = 0.63).

Analysis of observations, interviews, and documentation revealed several important findings. First, there was an improvement in the ability to express ideas in writing. At the beginning of the lesson, students tended to write short answers without explanations. After following the learning trajectory, students' answers became more elaborate, using precise mathematical terms and systematic explanations.

Second, oral communication skills improved significantly. Observations showed an increase in the frequency and quality of group discussions. In the initial meeting, students were hesitant and often used colloquial language. By the final meeting, they were more confident in using appropriate mathematical terminology in presentations and discussions.

Third, the ability to use mathematical representations is well developed. Students are able to create accurate diagrams, graphs, and geometric sketches. They can also use mathematical notation (functions, equations, formulas) correctly and provide verbal explanations using correct mathematical language.

Fourth, cultural context makes learning more meaningful and increases motivation. Interviews with students revealed: "I've always studied mathematics by memorizing formulas without understanding their use. Now I see mathematics all around us, in traditional houses, in songket, and even in the way mothers sell at the market. Mathematics has become more interesting." The motivation questionnaire showed an average score of 4.3 (high category), with 94.4% of students stating that learning is more interesting with a cultural context.

The highest improvement occurred in oral mathematical communication (N-Gain = 0.63). This finding may be attributed to the collaborative nature of Minangkabau culture-based activities, particularly traditional market simulations and group discussions. These activities required students to negotiate meaning, explain mathematical reasoning, and defend their solutions verbally. Similar findings were reported by Utami (2022) in Javanese culture-based learning and Sari and Valentino (2021) in Malay culture-based learning, where culturally meaningful contexts encouraged active classroom discourse. However, unlike previous studies that primarily reported gains in conceptual understanding and learning motivation, this study specifically demonstrates improvement in mathematical communication skills through a structured learning trajectory approach.

The research results show that a Minangkabau culture-based learning trajectory effectively improves students' mathematical communication skills. This finding aligns with (Vygotsky, 1978) social constructivism theory, which emphasizes the importance of cultural context in learning. When students learn mathematics in familiar and meaningful contexts, they more easily construct understanding and communicate mathematical ideas.

Factors that contribute to success include: (1) Authentic and meaningful contexts that make mathematics learning no longer abstract; (2) Structured scaffolding from simple to complex activities according to the Zone of Proximal Development; (3) Collaborative learning that provides opportunities to practice mathematical communication; (4) Multiple representations that help in-depth understanding; (5) Cultural identity that increases positive emotional engagement with mathematics.

Although effective, the implementation of this learning trajectory faces several challenges: (1) Availability of learning resources - not all schools have access to cultural artifacts or museums; (2) Learning time - requires more time than conventional learning; (3) Teacher competence - requires a deep understanding of local culture and the ability to design contextual learning; (4) Assessment - requires a comprehensive rubric and time for scoring.

CONCLUSION

This study successfully developed a valid Minangkabau culture-based learning trajectory consisting of six interconnected learning activities integrating Rumah Gadang architecture, songket motifs, traditional measurement systems, market activities, cultural statistics, and project-based learning. The trajectory was designed according to design research principles and supported students' progressive development of mathematical communication skills.

The implementation in SMA Negeri 3 Padang showed that the learning trajectory was effective in improving students' mathematical communication skills, as indicated by a significant increase in post-test scores and a moderate N-Gain value (0.59). The greatest improvement occurred in oral communication skills. Nevertheless, these findings are limited to the context of Grade XI students at SMA Negeri 3 Padang and should be interpreted within this setting.

Future researchers are encouraged to investigate the implementation of ethnomathematics-based learning trajectories in different cultural settings and mathematical topics to examine their generalizability. Further studies should also explore strategies for overcoming practical constraints such as limited instructional time and teachers' limited experience in designing ethnomathematics-based learning activities. Professional development programs focusing on local-culture integration and learning trajectory design are recommended to support broader implementation.

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