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Development of Project-Based Mathematics Learning Materials Integrating East Javanese Ethnomathematics to Improve Fourth-Grade Students' Geometry Learning Outcomes

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Abstract

Many elementary students still struggle to connect mathematical concepts to real-life contexts, particularly in geometry, due to traditional teaching practices that rely on rote memorization rather than conceptual understanding. This study addresses these issues by developing project-based learning materials enriched with ethnomathematical content drawn from East Javanese culture to enhance fourth-grade students' understanding of plane geometry. The research utilized the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) within a one-group pretest–posttest design involving 26 fourth-grade students from MI Unggulan Roudlotul Ulum, Sidoarjo. Data were collected through observations, interviews, questionnaires, tests, and documentation. Results indicated that the developed materials aligned well with curriculum requirements and student learning needs, incorporating cultural elements such as traditional games and crafts into project activities. Feasibility evaluations from content experts (92%), design experts (94%), and practitioners (90%) confirmed that the materials were highly valid and practical. The paired-sample t-test ($p < 0.05$) demonstrated significant improvements in learning outcomes, while qualitative feedback showed strong engagement, increased confidence, and cultural appreciation. These findings suggest that integrating ethnomathematics into project-based instruction can strengthen contextual learning, foster cultural awareness, and improve conceptual understanding in elementary mathematics education.

Keywords: Ethnomathematics; Learning Outcomes; Project-Based Learning; Teaching Material Development

Abstrak

Salah satu permasalahan yang sering muncul di sekolah dasar adalah kesulitan siswa dalam memahami dan mengaitkan konsep geometri bangun datar dengan pengalaman sehari-hari. Hal ini disebabkan oleh pendekatan pembelajaran yang masih berfokus pada hafalan rumus dan latihan mekanis, bukan pada pemahaman konseptual yang bermakna. Penelitian ini bertujuan untuk mengembangkan bahan ajar berbasis proyek (*Project-Based Learning*) yang dipadukan dengan muatan etnomatematika khas Jawa Timur untuk meningkatkan pemahaman konsep dan hasil belajar matematika siswa kelas IV pada materi bangun datar. Penelitian ini menggunakan metode penelitian dan pengembangan (*Research and Development*) dengan model ADDIE (*Analysis, Design, Development, Implementation, Evaluation*) dan desain *one-group pretest–posttest* yang melibatkan 26 siswa MI Unggulan Roudlotul Ulum Sidoarjo. Data dikumpulkan melalui observasi, wawancara, angket, tes, dan dokumentasi. Hasil penelitian menunjukkan bahwa bahan ajar yang dikembangkan telah sesuai dengan kebutuhan belajar siswa serta capaian pembelajaran yang berlaku. Integrasi unsur budaya lokal seperti permainan tradisional *engklek*, pola *batik*, dan bentuk makanan khas daerah menjadikan pembelajaran lebih kontekstual dan menarik. Penilaian kelayakan oleh ahli materi, desain, dan praktisi menunjukkan kategori "sangat valid" sehingga bahan ajar layak digunakan dalam pembelajaran. Analisis uji-t berpasangan menunjukkan peningkatan hasil belajar siswa yang signifikan secara statistik ($p < 0,05$). Selain itu, siswa menunjukkan minat, keterlibatan, dan apresiasi tinggi terhadap budaya lokal selama proses pembelajaran. Temuan ini mengindikasikan bahwa integrasi etnomatematika dalam pembelajaran berbasis proyek dapat menjadi strategi efektif untuk memperkuat pembelajaran kontekstual, meningkatkan hasil belajar, serta menumbuhkan kesadaran budaya dan karakter siswa sejak dini.

Kata Kunci: Etnomatematika; Hasil Belajar; Pembelajaran Berbasis Proyek; Pengembangan Bahan Ajar

Introduction

Mathematics learning in the 21st century emphasizes not only computational proficiency but also the ability to apply mathematical concepts to real-world contexts (Stacey, 2017). However, Indonesian students continue to perform below the OECD average in contextual problem-solving, as reflected in the 2019 PISA results (OECD, 2019). This low performance highlights a persistent challenge in developing students' higher-order thinking and real-life mathematical reasoning skills, which are key competencies for the modern era.

At the elementary level, many students struggle to connect abstract geometric concepts with concrete, everyday experiences. Learning processes that still prioritize rote memorization of formulas and repetitive drills tend to limit students' understanding and curiosity. To improve the quality of mathematics education, it is therefore essential not only to adopt innovative pedagogical strategies but also to develop contextual, relevant, and culturally meaningful

teaching materials. Effective teaching materials should align with learning objectives, support differentiated learning needs, and bridge school knowledge with students' lived experiences (Cahyadi, 2019).

Observations at MI Unggulan Roudlotul Ulum Sidoarjo revealed that students often struggled to calculate the perimeter and area of plane figures and failed to associate them with familiar objects. Teachers frequently had to re-explain basic concepts, indicating that students had limited conceptual comprehension. This local problem mirrors the broader national issue of insufficient contextualization in mathematics instruction. Thus, teaching materials that connect mathematical ideas with cultural and environmental contexts are urgently needed.

One promising approach to achieve this is through ethnomathematics, a concept introduced by D'Ambrosio, which explores how mathematical ideas are embedded in cultural practices, artifacts, and traditions (Rosa & Orey, 2016). In East Java, geometric and arithmetic patterns can be found in *batik* motifs, *engklek* (hopscotch) games, weaving, and traditional architecture. Integrating such local wisdom into classroom learning allows students to construct mathematical understanding meaningfully while fostering pride in their cultural identity (Aprilianingsih & Rusdiana, 2020). Empirical evidence supports this: Mulyasari et al. (2021) showed that incorporating traditional games improved spatial reasoning, while Arisetyawan et al. (2020) found that a lack of cultural connection hampers students' ability to apply mathematics to real-world problems.

At the same time, Project-Based Learning (PjBL) offers a pedagogical framework that promotes inquiry, collaboration, and problem-solving through hands-on projects (Thomas, 2000). PjBL model encourages students to construct knowledge by creating tangible outcomes linked to real-life situations. When combined with ethnomathematics, it creates a dual-layered learning experience—culturally grounded and inquiry-based—that stimulates students' engagement and critical thinking (Suryaningsih & Putriyani, 2022). For instance, students can calculate the area of traditional floor patterns or design ornaments inspired by local symmetry motifs, thus merging mathematical logic with cultural creativity.

Although numerous studies on PjBL or ethnomathematics have been conducted independently (Muhammad, 2018; Sustanto, 2022), few have investigated their integrated application in elementary geometric learning. This limited integration constitutes a research gap that restricts our understanding of how culturally contextualized project-based materials can systematically improve learning outcomes. Therefore, this study aims to address this gap by developing and

validating project-based mathematics teaching materials that integrate East Javanese ethnomathematics. The objectives of this study are to:

1. To design and validate project-based learning materials integrating ethnomathematical contexts for fourth-grade plane geometry; and
2. To evaluate their feasibility and effectiveness in improving students' conceptual understanding and learning outcomes.

The novelty of this study lies in combining two complementary approaches, PjBL and ethnomathematics, in the development of contextual mathematics teaching materials. This integration is expected not only to enhance mathematical achievement but also to cultivate cultural appreciation and identity formation among elementary school students. Finally, field interviews with teachers at MI Unggulan Roudlotul Ulum confirmed that students' average geometry scores often fell below the Minimum Learning Mastery Criteria (KKTP) of 75, consistent with previous studies (Monalisa et al., 2021). Considering that geometric concepts are deeply rooted in students' daily environments through shapes, spaces, and patterns, the development of ethnomathematics-integrated project-based materials provides a relevant and timely pedagogical innovation to address these challenges.

Method

The research utilized the ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation, as the main framework. This model was selected because the systematic and iterative nature of ADDIE is particularly suited for developing instructional materials that require continuous validation and revision at every stage, an essential process in designing culturally contextual, project-based mathematics resources. Unlike broader R&D models such as Borg and Gall, ADDIE provides a more practical cycle that aligns directly with classroom-based material development and formative evaluation needs (Branch & Dousay, 2015; Sugiyono, 2019).

Analysis Phase

This phase focused on identifying problems, needs, and potential solutions to guide the development of relevant teaching materials. The analysis included:

1. Curriculum Review, to map Learning Outcomes (Capaian Pembelajaran/CP) and Learning Objectives (Tujuan Pembelajaran/TP) related to elementary-level plane geometry.

2. Learner Characteristics Analysis, which reviewed students' cognitive development and learning difficulties based on observations and interviews with the fourth-grade mathematics teacher at MI Unggulan Roudlotul Ulum.
3. Learning Context Identification, to understand classroom conditions, available media, and the cultural environment to ensure integration with East Javanese ethnomathematics.
4. Problem Identification, which determined that students' main difficulties lay in conceptual understanding, applying formulas, and connecting geometric ideas with daily experiences.

The results of this phase served as the foundation for designing teaching materials that are both culturally contextual and aligned with curriculum demands.

Design Phase

In this stage, a conceptual blueprint for the teaching materials was developed. It consisted of the following elements:

a. Learning Objectives and Indicators, which were formulated based on the CP and TP of the Indonesian curriculum.
b. Content Mapping, which included topics on the perimeter and area of triangles and quadrilaterals.
c. Integration of East Javanese Cultural Contexts, such as *batik* patterns, *engklek* (hopscotch), and *tempe* shapes, to serve as project materials.
d. Selection of Learning Strategies, which adopted the Project-Based Learning (PjBL) approach, emphasizing student collaboration, investigation, and product creation.

The instruments designed at this stage included:

1. Expert validation sheets (content, design, and practicality),
2. Student response questionnaires,
3. Observation sheets, and
4. Pretest–posttest instruments to assess learning outcomes.

The student response questionnaire consisted of 10 items designed to measure students' affective responses toward the developed materials. The indicators assessed were:

1) Students' engagement and enjoyment during project activities,
2) Confidence in understanding and solving geometry problems,

3) appreciation of the cultural elements integrated into the learning process, such as traditional foods, games, and crafts incorporated in the projects. Each item used a five-point Likert scale ranging from *strongly disagree (1)* to *strongly agree*
4) The questionnaire was validated by experts for content clarity and relevance.

Development Phase

The draft version of the teaching materials was then developed based on the established design specifications. This prototype underwent expert validation by three categories of evaluators: a content expert, an instructional design expert, and a practitioner (elementary school teacher). The validation process assessed the materials' content accuracy, pedagogical suitability, and visual and structural design (Sugiyono, 2019). The feasibility level of the product was calculated using the following formula:

$$\text{Feasibility Percentage} = \frac{\text{Actual Score}}{\text{Maximum Score}} \times 100\%$$

The criteria for interpreting the results were as follows on Table 1.

Table 1. Feasibility Criteria for Teaching Materials

Percentage (%)	Category
81 – 100%	Very Valid
61 – 80%	Valid
41 – 60%	Fairly Valid
21 – 40%	Less Valid
0 – 20%	Not Valid

Materials scoring in the "Valid" or "Very Valid" category were deemed feasible without major revisions, whereas products falling below this threshold were revised accordingly.

Implementation Phase

After expert validation, the developed materials were implemented in a real classroom setting involving 26 fourth-grade students at MI Unggulan Roudlotul Ulum Pilang, Sidoarjo. A purposive sampling technique was employed based on criteria such as consistent attendance, teacher recommendation, and identified learning difficulties in geometry. The learning process was conducted over several sessions, during which students engaged in project-based tasks using the developed materials. Data were collected using the following techniques:

1. Observation, to monitor students' engagement, collaboration, and use of cultural contexts;

2. Questionnaires, to capture students' perceptions and responses;
3. Cognitive assessments (pre-test and post-test), to measure learning gains. The cognitive test consisted of 10 multiple-choice and 5 short-answer items, developed based on learning indicators derived from the Learning Outcomes (CP) and Learning Objectives (TP) for fourth-grade plane geometry. The indicators measured:
    1) students' ability to identify geometric shapes in everyday objects,
    2) calculate the perimeters of triangles and quadrilaterals,
    3) calculate areas of triangles and quadrilaterals, and
    4) apply geometric formulas in contextual and culturally grounded problems (e.g., determining the area of *batik* patterns or *engklek* fields).

The items were validated by experts and revised for content clarity before use in the pretest and posttest sessions. To ensure the appropriateness of statistical analysis, the study first conducted a Shapiro–Wilk normality test ($n < 30$) to verify the normal distribution of the data. Then, a paired-sample t-test was applied to examine the significance of differences between pre-test and post-test scores.
The criteria for determining effectiveness were as follows:

a. *p-value* < 0.05 indicates significant improvement in learning outcomes; or
b. N-Gain ≥ 0.3 indicates medium to high effectiveness.

Evaluation Phase

The final phase involved both formative and summative evaluations to assess the overall feasibility and effectiveness of the teaching materials. The primary indicator of effectiveness was the difference in students' learning outcomes before and after the intervention, analyzed through pre-test and post-test results.

To ensure statistical validity:

1. A Shapiro-Wilk normality test was first conducted using SPSS version 26, as this test is suitable for small sample sizes ($n < 30$) (Ghozali, 2018).
2. Upon confirming normality, a paired-sample t-test was employed to assess the significance of differences between pre- and post-test scores (Field, 2018).
3. The null hypothesis (H_0), which stated that no significant difference existed between pre-test and post-test scores, was rejected if the computed t-value exceeded the critical t-table value at the 5% significance level or if the p-value was less than 0.05.

4. A statistically significant result would confirm that the developed teaching materials had a positive impact on students' mathematical learning outcomes (Pallant, 2020).

Results

This study produced project-based mathematics teaching materials infused with ethnomathematics content, developed through the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The findings of each phase are presented in the following subsections.

Analysis Phase

A needs analysis was conducted through interviews with mathematics teachers and classroom observations in grade IV at MI Unggulan Roudlotul Ulum. Key findings revealed that existing learning materials were heavily focused on formula memorization and lacked contextual relevance. Students encountered significant challenges in plane geometry, including difficulties in applying formulas and interpreting word problems. These insights laid the groundwork for designing culturally contextual teaching resources.

Design Phase

Based on the findings, the instructional goals were defined, and learning activities were designed around East Javanese cultural elements (e.g., traditional games, foods, and crafts). The materials included guided projects aligned with geometry topics (perimeter and area of 2D shapes), project worksheets, reflection sheets, and culturally integrated illustrations. Research instruments such as expert validation forms, student response questionnaires, and pretest–posttest assessments were also developed during this stage.

Development Phase

The teaching materials were developed in printed module form and were subsequently validated by three experts: a content expert, an instructional design expert, and a practitioner (classroom teacher). Validation results are shown in Table 2.

Table 2. Expert Validation Results

Validator	Score (%)	Category
Content Expert	92	Very Valid
Design Expert	94	Very Valid
Practitioner Expert	90	Very Valid

According to the feasibility criteria, all validation scores fell within the "Very Valid" range (81–100%). This confirmed that the developed materials fulfilled all expert assessment dimensions for both content and media aspects. From the material expert review, the content was evaluated as accurate, relevant to the curriculum, and aligned with the Learning Outcomes (CP) and Learning Objectives (TP). The inclusion of ethnomathematical contexts, such as *batik* symmetry, *engklek* patterns, and local crafts, was deemed appropriate for representing East Javanese culture and effectively connecting mathematics to real-life experiences. Meanwhile, the media and design experts emphasized that the structure of the materials followed the Project-Based Learning (PjBL) model, consisting of project introduction, planning, implementation, and reflection stages. The layout, visual clarity, and step-by-step activities were rated as well-organized, engaging, and feasible for classroom use without substantial revision. These findings indicate that the developed materials are not only valid in terms of content and design but also pedagogically consistent with the principles of contextual, culture-based project learning. The research findings may be organized according to each phase of the study or structured to address the research questions, provided that the outcomes of the conducted investigation are clearly presented and supported by empirical evidence.

Implementation Phase

The validated materials were implemented in a real classroom setting with 26 fourth-grade students. Students completed a series of geometry learning tasks and projects using the new materials over several sessions. Observations revealed high levels of engagement, collaboration, and curiosity among students. Students also participated in activities such as calculating the area of *tempe* shapes and creating floor patterns inspired by traditional *batik* motifs.

Evaluation Phase

To evaluate effectiveness, a pretest–posttest design was used. The average pretest score was 65.4 (SD = 8.2), while the posttest average rose to 82.7 (SD = 6.5).

This indicates a statistically meaningful improvement in students' geometry comprehension.

Table 3. Student Learning Outcomes

Test	N	Mean	SD
Pretest	26	65,4	8,2
Posttest	26	82,7	6,5

A Shapiro–Wilk test confirmed the data were normally distributed. A paired-sample t-test using SPSS version 26 yielded a statistically significant result ($p < 0.001$), The statistically significant improvement indicates that the use of the developed project-based ethnomathematics materials enhanced students' performance across all measured indicators of learning outcomes. Based on the pretest–posttest analysis, the most substantial gains were observed in:

1. recognizing and classifying plane figures in everyday cultural contexts (mean improvement = 20%),
2. calculating the perimeter and area of triangles and quadrilaterals accurately (mean improvement = 18%), and
3. applying geometric concepts to solve contextual and ethnomathematical problems, such as estimating areas of *batik* motifs or *engklek* fields (mean improvement =25%).

These findings confirm that the materials not only improved procedural understanding but also fostered conceptual and contextual comprehension aligned with the Learning Outcomes (CP) and Learning Objectives (TP). Each indicator demonstrated measurable progress, ensuring that the improvement was pedagogically meaningful in addition to being statistically significant.

Student Feedback

Findings from post-lesson questionnaires indicated that:

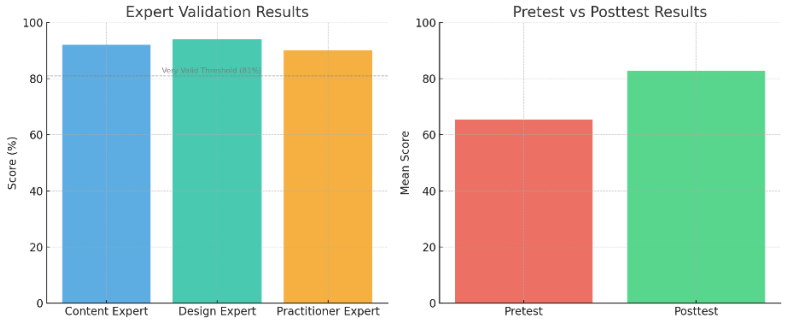
1. 92% of students found the learning materials engaging and enjoyable.
2. 88% indicated increased confidence in solving geometry problems.
3. 84% appreciated the use of cultural elements like traditional foods and games in the projects.

These responses suggest that the materials not only improved cognitive outcomes but also supported affective engagement and cultural appreciation. One student reflected, "I understand shapes better because we used real objects from our culture, such as making patterns with *tempe* and *engklek*."

Effectiveness in Improving Student Learning Outcomes

The implementation phase yielded a significant improvement in students' cognitive performance. As depicted in the right panel of Figure 1, students' average scores increased from 65.4 (pre-test) to 82.7 (post-test). A paired-sample t-test confirmed that this improvement was statistically significant ($p < 0.001$). This result strongly supports the hypothesis that project-based learning combined with ethnomathematics enhances conceptual understanding in elementary mathematics education (see Figure 1).

Figure 1. Expert Validation Results and Learning Outcome Improvements



Discussion

The findings of this study confirm the effectiveness of project-based mathematics teaching materials infused with ethnomathematical content in enhancing students' achievement and engagement in learning plane geometry. This discussion elaborates on the implications of the product validation results, learning outcomes, and student feedback.

As illustrated in the left panel of Figure 1, the expert validation scores ranged from 90% to 94%, classifying the materials firmly in the "Very Valid" category. These evaluations affirm the product's soundness in terms of content relevance, instructional coherence, and cultural integration, thereby supporting its pedagogical appropriateness. The consistency of positive evaluations from three independent experts also reflects high inter-rater agreement and reinforces the product's empirical feasibility.

These findings align with prior studies that emphasize the need for rigorous material validation in instructional product development (Zulnaidi & Zakaria, 2019; Suryani et al., 2020). Teaching materials that are pedagogically valid and

contextually relevant are more likely to improve both teacher confidence and student learning outcomes.

The findings of learning outcome improvements align with those of Mulyasari et al. (2021), who demonstrated that embedding traditional games in learning materials led to higher geometry comprehension. Similarly, Arisetyawan et al. (2020) highlighted how the lack of cultural context in school mathematics contributes to poor problem-solving skills. By grounding abstract geometric concepts in familiar cultural practices such as estimating area using *tempe* or exploring symmetrical patterns in *batik*, students could internalize and apply the mathematical ideas more effectively.

The inclusion of ethnomathematical elements contributed to both academic gains and positive affective outcomes. Over 88% of students reported enjoying the learning process and feeling more confident in solving geometry problems. The meaningful integration of East Javanese cultural elements helped create a learning environment that was both intellectually stimulating and emotionally engaging. This echoes findings by Aprilianingsih & Rusdiana (2020), who note that culturally relevant pedagogy fosters deeper learning and identity development in Indonesian classrooms.

Moreover, the use of Project-Based Learning (PjBL) created opportunities for collaboration, problem-solving, and reflective skills that are increasingly emphasized in 21st-century learning frameworks (Lestari & Purnomo, 2020). Projects involving local artifacts, for example, calculating the perimeter of an *engklek* game field, not only reinforced mathematical concepts but also cultivated appreciation for cultural heritage.

Conclusion

This study developed, validated, and evaluated project-based mathematics teaching materials that integrate East Javanese ethnomathematics to improve fourth-grade students' learning outcomes in plane geometry. The research process employed the ADDIE model, yielding materials that were empirically validated, pedagogically robust, and culturally meaningful. The findings demonstrate that the integration of ethnomathematical contexts within a Project-Based Learning (PjBL) framework can effectively enhance students' conceptual understanding, problem-solving skills, and engagement in mathematics. The "Very Valid" validation ratings from material, media, and practitioner experts indicate that the developed materials meet both content accuracy and instructional design quality. The effectiveness of the materials ($p < 0.001$) between pretest and posttest scores confirms the materials'

effectiveness in strengthening students' mastery of geometric concepts. Furthermore, the students' positive responses highlight the importance of incorporating local cultural elements to foster motivation, confidence, and appreciation for mathematics learning.

Beyond empirical validation, these results emphasize that ethnomathematics-based PjBL serves as a viable instructional model for contextualizing abstract mathematical concepts. It aligns with constructivist and culturally responsive learning theories, enabling students to connect mathematical reasoning with their sociocultural experiences. This approach also supports the national education agenda to integrate local wisdom into curriculum implementation, thereby contributing to the development of character and cultural identity among young learners. Theoretically, this study reinforces the significance of combining cognitive and cultural dimensions in mathematics education through project-based design. Practically, it provides a model for teachers and curriculum developers to design culturally grounded materials that are both engaging and effective. Future research should expand on this study by implementing digital or hybrid versions of the developed materials to enhance accessibility, interactivity, and scalability; testing the materials across multiple schools or regions to examine their scalability and cultural adaptability; and exploring teacher training programs that integrate ethnomathematics-based project learning to strengthen pedagogical competence. Through these directions, future studies can further optimize the role of ethnomathematics and PjBL in promoting contextualized, inclusive, and culturally responsive mathematics education in Indonesia and beyond.

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