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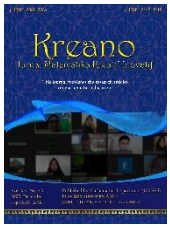

Integration of Ethnomathematics-Project-Based-Learning to Enhance Understanding of Geometric Transformations

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Abstract

Transformation geometry is an important topic in mathematics education. However, undergraduate instruction is often abstract and focused on procedures, which limits students' conceptual understanding. Project-Based Learning and ethnomathematics are known to support meaningful learning. Nevertheless, studies that integrate ethnomathematics into a Project-Based Learning framework for teaching transformation geometry in mathematics education programs are still limited. This study aims to develop and evaluate an ethnomathematics-based PjBL model to improve students' understanding of transformation geometry. The research employed a research and development (R&D) approach using the ADDIE model, encompassing the Analysis, Design, Development, Implementation, and Evaluation stages. The study was conducted with second-year undergraduate students enrolled in a Transformation Geometry course in the Mathematics Education program at Universitas PGRI Palembang. Ethnomathematical contexts drawn from local cultural practices, such as weaving patterns, wood carving motifs, and traditional architecture, were integrated into project-based learning activities. Data were collected through expert validation sheets, pretest–posttest instruments, observation sheets, and student response questionnaires. The results indicate that the developed learning model is valid, as evidenced by expert assessments of content, pedagogy, and media; practical, based on high levels of implementation and positive student responses; and effective, as shown by significant improvements in students' transformation geometry learning outcomes. These findings suggest that integrating PjBL with ethnomathematics offers a contextually grounded and pedagogically robust approach to enhancing conceptual understanding of transformation geometry at the undergraduate level.

Keywords: Ethnomatematics; PjBL; Geometric Transformations

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Abstrak

Geometri transformasi merupakan topik penting dalam pendidikan matematika. Namun, pembelajaran pada jenjang perguruan tinggi masih sering bersifat abstrak dan berfokus pada prosedur, sehingga membatasi pemahaman konseptual mahasiswa. Project-Based Learning dan etnomatematika telah dikenal mampu mendukung pembelajaran yang bermakna. Meskipun demikian, penelitian yang mengintegrasikan etnomatematika ke dalam kerangka Project-Based Learning untuk pembelajaran geometri transformasi pada program pendidikan matematika masih terbatas. Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi model Project-Based Learning berbasis etnomatematika guna meningkatkan pemahaman mahasiswa terhadap geometri transformasi. Penelitian ini menggunakan pendekatan penelitian dan pengembangan (Research and Development) dengan model ADDIE yang meliputi tahap analisis, perancangan, pengembangan, implementasi, dan evaluasi. Penelitian dilaksanakan pada mahasiswa semester dua yang mengikuti mata kuliah Geometri Transformasi pada Program Studi Pendidikan Matematika di Universitas PGRI Palembang. Konteks etnomatematika yang bersumber dari praktik budaya lokal, seperti motif tenun, ukiran kayu, dan arsitektur tradisional, diintegrasikan ke dalam kegiatan pembelajaran berbasis proyek. Data dikumpulkan melalui lembar validasi ahli, instrumen pretest–posttest, lembar observasi, dan angket respons mahasiswa. Hasil penelitian menunjukkan bahwa model pembelajaran yang dikembangkan bersifat valid berdasarkan penilaian ahli terhadap aspek materi, pedagogik, dan media; praktis berdasarkan tingkat keterlaksanaan yang tinggi dan respons positif mahasiswa; serta efektif yang ditunjukkan oleh peningkatan hasil belajar geometri transformasi mahasiswa secara signifikan. Temuan ini menunjukkan bahwa integrasi Project-Based Learning dengan etnomatematika menawarkan pendekatan pembelajaran yang kontekstual dan kuat secara pedagogis untuk meningkatkan pemahaman konseptual geometri transformasi pada jenjang perguruan tinggi.

INTRODUCTION

Students' difficulties in understanding geometry, particularly in solving problems related to space and shape, remain a persistent challenge in mathematics education. This issue is not merely theoretical, but is reflected in empirical evidence from large-scale international assessments. The Programme for International Student Assessment (PISA) consistently reports low student achievement in geometry-related domains, indicating weaknesses in spatial reasoning and conceptual understanding. In Indonesia, these results highlight a critical gap between expected mathematical competencies and students' actual performance (OECD, 2023). Geometry, which is fundamental for developing spatial visualization and supporting applications in science, technology, and everyday problem solving, has therefore become an urgent area of concern in mathematics instruction. Addressing this issue requires instructional approaches that move beyond procedural learning and enable students to construct meaningful geometric understanding.

Addressing the complexity and demands of 21st-century education requires not only updating teachers' content knowledge but also enhancing their pedagogical skills. Classroom realities demonstrate that mastery of concepts and theories alone is insufficient for delivering authentic learning experiences (dos Santos et al., 2018). Modern education calls for teachers who can guide learners in independently managing knowledge and developing essential competencies such as research skills, problem-solving, project management, collaboration, analytical and synthetic thinking, and effective communication. Consequently, teaching approaches must be transformed to foster holistic and contextual student development, making mathematics instruction more meaningful.

Transformation geometry represents a critical yet problematic component of geometry learning, as it demands students to mentally manipulate objects and reason about invariant properties under change. In classroom practice, students are often required to apply formulas or procedures for translation, reflection, rotation, and dilation without a clear understanding of the underlying geometric relationships (Jones, 2000; Sari et al., 2022) . As a result, many students can perform routine tasks but fail to explain or visualize the effects of transformations on geometric objects (Kandaga et al., 2023; Napfiah & Sulistyorini, 2021; Trisna et al., 2022).

Preliminary observations in a Geometry Transformation course within a Mathematics Education program revealed that many undergraduate students had difficulty visualizing and explaining geometric transformations. Students tended to rely on memorizing formulas and step-by-step procedures, but struggled to interpret the meaning of transformations or relate them to real objects. Classroom activities were mainly lecture-based, with limited opportunities for students to explore concepts through hands-on or contextual tasks. As a result, students often perceived transformation geometry as abstract and difficult. This situation indicates that the challenge in learning transformation geometry lies not only in the abstract nature of the concepts (Zulkardi, 2002), but also in instructional approaches that emphasize procedural completion over conceptual meaning and spatial reasoning.

At the same time, the learning environment provided rich cultural resources that were not utilized in instruction. Local cultural products, such as batik motifs, woven fabrics, and traditional buildings, contain clear examples of symmetry, rotation, translation, and dilation. However, these cultural elements were rarely incorporated into course activities or assignments. This gap between students' learning needs and available cultural contexts indicates a practical need for a learning model that connects transformation geometry to students' real experiences

The main issue lies in teaching methods that are overly abstract, conventional, and lacking in cultural relevance (Albab et al., 2014). Prior studies predominantly focus on digital media or general instructional models, often neglecting the integration of cultural contexts that could enhance the meaning and relevance of mathematical learning (Rosa & Orey, 2016). Ethnomathematics addresses this gap by embedding local culture into the learning process (Par & Prasetyo, 2024). This approach allows students to understand mathematical concepts through familiar cultural practices, artifacts, and values, thus increasing engagement and comprehension (Fauzi & Setiawan, 2020).

Similarly, PjBL has been shown to be effective in promoting conceptual understanding through authentic experiences and collaborative work (Retno et al., 2025; Savery & Duffy, 2001; Thomas, 2000). It nurtures 21st-century skills, including critical thinking, collaboration, communication, creativity, innovation, self-direction, and both local and global connections (Denuga & Nkengbeza, 2022).

Project-Based Learning (PjBL) offers a learning approach that positions students as active participants in constructing knowledge through meaningful tasks. In mathematics classrooms, PjBL allows students to explore problems, discuss ideas with peers, and develop solutions based on reasoning rather than routine procedures (Bell, 2010; Thomas, 2000). Through project work, students are encouraged to connect mathematical concepts with real situations, which supports deeper conceptual understanding and higher-order thinking (Jeniver et al., 2023; Yulianto et al., 2024). Such characteristics make PjBL particularly relevant for addressing learning challenges in topics that require strong visualization and reasoning, such as geometry. Integrating Project-Based Learning with ethnomathematics offers a relevant approach to address these challenges by engaging students in meaningful projects grounded in their local culture.

Accordingly, this study occupies a strategic position in addressing the existing gap by developing an ethnomathematics-based PjBL model whose validity, practicality, and effectiveness have been rigorously tested in improving students' understanding of geometric transformations. While research on PjBL and ethnomathematics has progressed, the integration of these two approaches in teaching geometric transformations remains underexplored. Recent studies highlight the strong potential of this integration: a meta-analysis by (Pratama & Yelken, 2024) reported that ethnomathematics-based instruction exerts a substantial effect on mathematical literacy, including in transformation geometry. Furthermore, integrating PjBL with ethnomathematics has been demonstrated to enhance critical thinking skills and learning motivation, as evidenced in (Syaripah, 2025) research on transformation geometry learning. A systematic review by (Iskandar et al., 2022) also indicated that geometric concepts embedded in cultural heritage, such as batik motifs and architectural ornaments, represent valuable resources for ethnomathematics-based instruction.

While (Pratama & Yelken, 2024) meta-analysis confirms the strong influence of ethnomathematics on mathematical literacy, it does not specifically address PjBL. Nevertheless, integrating PjBL with ethnomathematics holds considerable promise for delivering more contextual and meaningful transformation geometry learning—for instance, by using cultural artifacts such as the Lagosi motif to illustrate translation and reflection (Pathuddin & Busrah, 2024). In addition, (Dwirahayu et al., 2024) reported that PjBL in transformation geometry effectively strengthens the Pedagogical Content Knowledge (PCK) of prospective mathematics teachers.

This approach enables students to explore geometric transformations through cultural objects such as symmetrical batik, woven patterns, and traditional architecture, while collaboratively constructing knowledge through meaningful project work. Although previous studies have discussed Project-Based Learning and ethnomathematics separately, there is still a lack of research that systematically develops and evaluates an ethnomathematics-based PjBL model specifically for teaching transformation geometry known_celebrity at the undergraduate level, particularly in mathematics education programs. Moreover, existing studies rarely focus on the design and validation of learning models that integrate local cultural contexts into project-based activities within a formal geometry course.

This study positions itself as a design-oriented contribution by producing a validated, practical, and effective learning model that can be implemented by lecturers in geometry courses. By doing so, the model is expected to support students in achieving the required competencies in transformation geometry and to contribute to the preparation of prospective mathematics educators who possess strong conceptual understanding and cultural awareness.

METHOD

This study employed a Research and Development (R&D) method using the ADDIE instructional design model, which comprises five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE framework was selected as it provides systematic steps for designing, developing, and evaluating instructional materials to ensure their feasibility for classroom use (Branch, 2009; Sugiyono, 2015). The research was conducted during the even semester of the 2024/2025 academic year at a higher education institution in South Sumatra, involving 28 students enrolled in the Mathematics Education Study Program who were taking the Transformation Geometry course. The selection of participants was based on their engagement in learning transformation geometry, the availability of time and resources, and access to local cultural experts such as traditional songket weavers.

Analysis: At this stage, students' learning difficulties in transformation geometry were identified through classroom observations and informal interviews with the course lecturer. The analysis revealed that students consistently struggled with reflection, rotation, translation, and dilation when instruction was abstract and formula-oriented. Learner characteristics, prior knowledge, course learning outcomes, and basic competencies were examined. In addition, a cultural analysis was conducted through direct observation of South Sumatran songket motifs that exhibit geometric transformations. The results of this analysis informed the design of a culture-based project requiring students to apply at least three types of geometric transformations. This informed a project requiring students to apply at least three transformation types to culture-based objects.

Design: We prepared the lesson plan, student worksheets, media, and assessments. The LKPD guided students to recognize and apply transformations to local objects, anchored by the inquiry, "How can transformation patterns in songket be developed into motifs that are both aesthetic and mathematically sound?" Rubrics evaluated conceptual accuracy, creativity, cultural relevance, and collaboration.

Development: All instructional materials and assessment tools were developed and validated by three experts in mathematics education. The expert panel consisted of two senior lecturers in mathematics education with experience in geometry instruction and instructional design, and one expert in mathematics education research with a background in curriculum development and learning media. The validation focused on content accuracy, language clarity, instructional design, and visual presentation. Revisions were made based on expert feedback. After validation, a limited trial was conducted with 6–8 students to examine readability, clarity of instructions, and feasibility of the project activities. Data from this stage were analyzed descriptively and used to refine the learning materials before field implementation.

Implementation: The integration of ethnomathematics and Project-Based Learning (PjBL) was operationalized through a sequence of culture-based project activities embedded in the Transformation Geometry course. Students worked in small groups to investigate geometric transformations found in South Sumatran songket motifs. Each project required students to (1) identify types of transformations present in cultural patterns, (2) mathematically analyze the transformations using coordinate geometry, (3) redesign or extend the motifs through digital tools by applying translation, reflection, rotation, and dilation, and (4) present and justify their designs based on mathematical accuracy and cultural relevance. The lecturer acted as a facilitator by guiding inquiry, monitoring collaboration, and providing feedback during each project phase.

At this phase we also find the practicality of the development PjBL model. Practicality was evaluated through observation sheets measuring the level of implementation and student participation, as well as student response questionnaires assessing ease of use, clarity of instructions, and engagement. High levels of implementation and positive student responses indicated that the model was practical.

Evaluation: Evaluation was conducted using quantitative and qualitative approaches. Quantitative data were collected using a pretest and posttest consisting of 3 structured essay questions. The test measured students' understanding of reflection, translation, rotation, and dilation. The items focused on identifying transformations, using coordinate representations, and explaining transformation processes. The test items were designed to measure students' understanding of geometric transformations using ethnomathematical contexts.

The first set of questions uses the Parang batik motif as the context. Students are asked to determine the image of a plane figure after a coordinate translation. They are then required to identify the image resulting from a translation followed by a reflection. In addition, students explain repeated patterns in the batik motif as examples of repeated geometric transformations. The second set of questions is based on Palembang songket patterns. Students determine the image of a rhombus after reflection across the x-axis. They also identify the image produced by a reflection followed by a 180-degree rotation. Finally, students explain the meaning of geometric transformations found in songket patterns as part of cultural pattern analysis. The third set of questions uses ornaments from Rumah Limas, a traditional house. Students determine the image of a kite-shaped figure after reflection across the line $y = 5$. They then determine the image after a reflection followed by a dilation with a scale factor of one half. In the final question, students explain the meaning of geometric transformations found in traditional carving motifs related to Rumah Limas, including their cultural significance. The test was validated by mathematics education experts, and reliability was confirmed through internal consistency analysis. Pretest and posttest scores were analyzed using a paired-samples t-test.

Qualitative data were collected through classroom observations and student questionnaires. The questionnaire consisted of 10 statements related to clarity of instruction, ease of use, student engagement, collaboration, and cultural relevance. Observation sheets focused on student participation, group interaction, and the implementation of project activities. Qualitative data were analyzed descriptively by summarizing responses and observation results based on the defined indicators. Effect size was calculated using Cohen's d to measure the magnitude of the model's effectiveness. The combination of limited and field trials, supported by statistical and qualitative analyses, was used to determine the effectiveness of the ethnomathematics-based PjBL model.

RESULT AND DISCUSSION

Results

This study aims to develop and evaluate the feasibility of an ethnomathematics-based Project-Based Learning (PjBL) model for teaching transformation geometry that is valid, practical, and effective for use in higher education. These objectives were achieved through a series of development stages following the ADDIE model, beginning with needs analysis and culminating in the final evaluation. Accordingly, the findings of this research are presented in the order of the development stages, allowing the connection between the processes undertaken and the outcomes achieved to be clearly demonstrated. A detailed description of the research findings is presented as follows.

Analysis

The analysis stage focused on identifying instructional needs through classroom observations, student interviews, and curriculum document analysis. This stage also involved identifying local cultural motifs that could be meaningfully integrated into transformation geometry learning. The findings from these activities revealed several important issues related to students, instruction, and learning resources.

Data reduction results showed that many students experienced difficulties in spatial visualization, particularly in understanding reflection, rotation, and translation. Classroom instruction tended to emphasize procedural problem solving and lacked contextual connections. Although students were familiar with local cultural elements, such as Palembang songket and Rumah Limas, they had never associated these cultural artifacts with mathematical concepts. In addition, lecturers expressed a need for teaching modules that are contextual, support creative project-based activities, and integrate local culture into geometry instruction.

Data presentation from multiple sources further supported these findings. Classroom observations indicated that existing learning media, activities, and worksheets did not connect transformation geometry with cultural contexts. Interview results showed that approximately 92% of students stated they understood transformation concepts more easily when visual cultural contexts were used. Document analysis revealed that previous teaching modules did not include Palembang ethnomathematical elements.

Based on these findings, it was concluded that Palembang local culture is highly appropriate to serve as a contextual foundation for developing an ethnomathematics-based Project-Based Learning module. Integrating local cultural motifs into PjBL activities is expected to improve students' conceptual understanding of transformation geometry.

Design

Building on this needs analysis, the Design stage translated insights into concrete learning goals and materials. The design stage resulted in four concrete instructional products that were specifically tailored to address the learning problems identified in the analysis stage: the lesson plan, student worksheets, learning media, and assessment instruments.

The lesson plan was designed to

operationalize the integration of Project-Based Learning and ethnomathematics in a Transformation Geometry course. It explicitly mapped learning objectives to project activities that required students to explore local cultural artifacts, such as Palembang songket motifs and Rumah Limas ornaments. The lesson plan emphasized problem exploration, group investigation, project creation, presentation, and reflection. Each learning session was structured to ensure that students actively identified and applied geometric transformations within cultural patterns rather than merely solving procedural exercises. The cover of lesson plan can be seen in Figure 1.

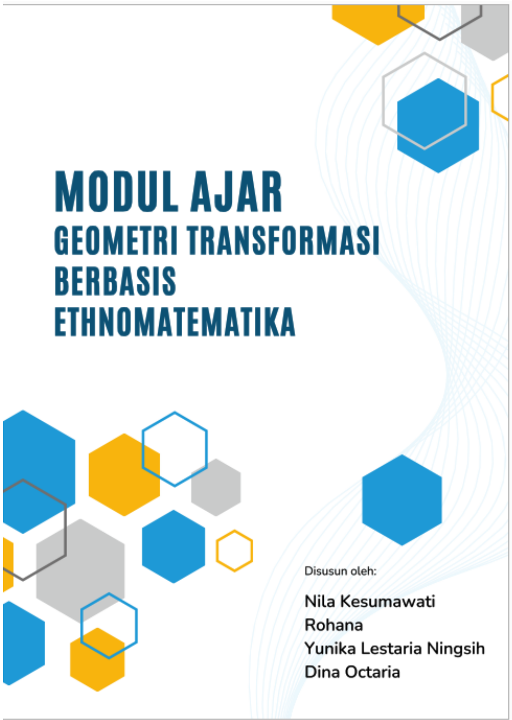


Figure 1. The Cover of Lesson Plan

The student worksheets were designed as the main learning scaffold during project activities. Each worksheet was developed based on findings that students needed support in spatial visualization and conceptual interpretation. Four worksheets were produced, focusing on translation, reflection, rotation, and dilation. Worksheet 1: Translation Based on Songket Motifs. This worksheet presents repeated songket patterns as learning material. Students identify translation in the motifs and use GeoGebra to move objects systematically. At the end of the activity, students draw conclusions about the concept of translation based on the songket patterns. Worksheet 2: Rotation Based on Songket Motifs and Rumah Limas. Motif images are presented as learning stimuli. Students analyze repeated shapes that represent rotations of 90°, 180°, or 270°. They perform point and shape rotations using GeoGebra and discuss why rotation is important in the process of making songket. Worksheet 3: Reflection Based on Rumah Limas Palembang. Symmetrical patterns and carvings from Rumah Limas are used as exploration media. Students determine the line of reflection in the carving motifs and draw the reflected images. They then check whether the reflected images match the original motifs. Worksheet 4: Dilation in Stair and Carving Motifs of Rumah Limas. Students observe enlargement and reduction patterns in carvings and stair motifs. They construct dilations with specific scale factors using GeoGebra. Students also discuss how craftsmen maintain proportional motifs using mathematical principles. Reflection sections were included to encourage students to connect mathematical concepts with cultural values and visual balance found in traditional designs.

The learning media were designed to strengthen visual understanding and contextual relevance. The media consisted of curated images and visual representations of songket patterns and Rumah Limas carvings that clearly exhibit geometric transformations. These visuals were selected and organized to highlight repetition, symmetry, rotation, and scaling patterns, responding directly to students' difficulties in recognizing transformations in abstract figures.

The assessment instruments were designed to measure conceptual understanding in a culturally grounded context. The pretest and posttest consisted of essay questions that required students to analyze geometric transformations embedded in cultural motifs rather than isolated geometric shapes. The items were aligned with indicators of understanding identified in the analysis stage, including identification of transformations, explanation of transformation processes, and interpretation of repeated patterns. This design ensured that assessment captured meaningful understanding rather than procedural recall. The result of test item indicator can be seen in Table 1.

In summary, the design stage produced instructional products that were not only structurally complete but also context-specific and problem-driven. Each product directly responded to the identified learning needs and served as a foundation for validation and refinement in the development stage.

Develop

With the design blueprint completed, the Development stage focused on transforming the planned design into usable instructional products, including the lesson plan, student worksheets (LKPD), learning media (photographs, sketches, and GeoGebra simulations), and

Table 1. The Test Item Indicator

No	Item Indicator	Content/ Competency	Cognitive Level	Item Number	Ethnomathematics Context
1	Determining the image of a plane figure after translation	Coordinate translation	C3 (Application)	1a	Parang Batik motif
2	Determining the image after translation followed by reflection	Translation and reflection	C4 (Analysis)	1b	Parang Batik motif
3	Explaining pattern repetition as repeated transformations	Pattern representation	C5 (Evaluation)	1c	Parang Batik motif
4	Determining the image of a rhombus after reflection across the x-axis	Reflection	C3 (Application)	2a	Palembang songket
5	Determining the image after reflection followed by 180-degree rotation	Reflection and rotation	C4 (Analysis)	2b	Palembang songket
6	Explaining the meaning of transformations in songket patterns	Cultural pattern analysis	C5 (Evaluation)	2c	Palembang songket
7	Determining the image of a kite after reflection across the line y = 5	Reflection across a horizontal line	C4 (Analysis)	3a	Rumah Limas ornament
8	Determining the image after reflection followed by dilation with scale factor 1/2	Reflection and dilation	C4 (Analysis)	3b	Rumah Limas
9	Explaining the meaning of transformations in carving motifs	Cultural value analysis	C5 (Evaluation)	3c	Rumah Limas

assessment instruments. These products were then reviewed by expert validators with backgrounds in mathematics education, Project-Based Learning, and ethnomathematics. The validation process examined four aspects: content, language, presentation, and graphical quality.

The validation results show that the experts assigned high average scores to all evaluated aspects. The content aspect obtained a validity score of approximately 93%, language 90%, presentation 91%, and graphical quality 92%, with an overall average exceeding 90%. Based on these results, the developed ethnomathematics-based Project-Based Learning (PjBL) model was categorized as very valid and feasible for classroom implementation. The detailed validity results are presented in Figure 2.

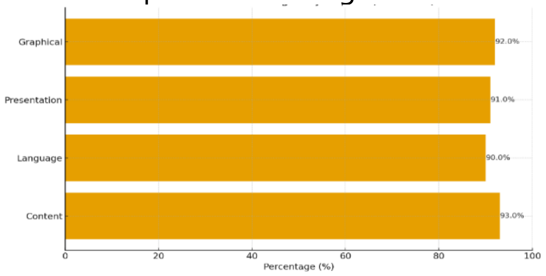


Figure 2.The Validity Test Result

According to Figure 2, the developed ethnomathematics-based Project-Based Learning (PjBL) model was declared highly feasible for use in classroom instruction. The validation results indicate that the model is appropriate in terms of content, language, presentation, and graphical aspects, making it suitable for implementation in mathematics learning.

Although the overall validity level was very high, the expert reviewers also provided constructive feedback for improvement. Revisions were mainly suggested to improve the clarity of instructions, strengthen the connection between cultural contexts and mathematical concepts, and enhance the precision of transformation tasks. In particular, some worksheet items were considered too implicit in describing initial conditions and transformation steps, which could lead to ambiguity for students. The example of revision can be seen in Table 2.

Table 2. Sample of the Revision

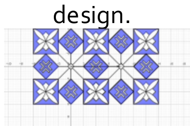
	Worksheet
Before	 a) A basic batik motif is formed by a triangle with vertices at A(1, 2), B(3, 2), and C(2, 4). b) Determine the image of triangle ABC after it is translated by the vector v = (4, 3). Then, reflect the translated figure across the y-axis. Determine the coordinates of the final image. c) Explain how this pattern mathematically represents the repetition of motifs in batik design.
After	 a) A fundamental batik motif can be modeled as a triangular figure with vertices at A(1, 2), B(3, 0), and C(2, 4). b) Determine the transformed image of triangle ABC after applying a translation defined by the vector v = (4, 3). c) Subsequently, apply a reflection of the translated vertex C with respect to the y-axis. Specify the coordinates of the resulting image. d) Provide a mathematical explanation of how this transformation pattern represents the repetitive structure of motifs in batik design.

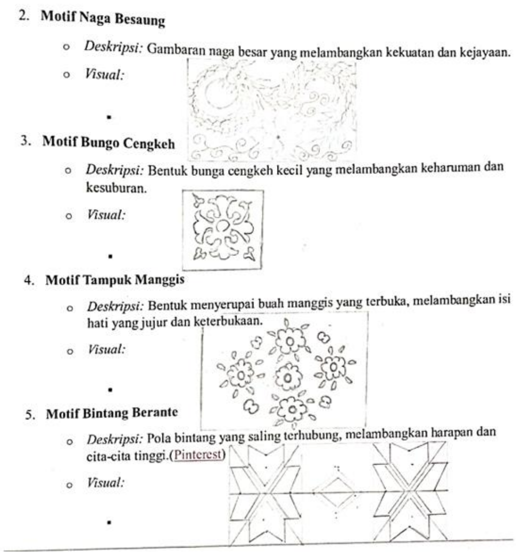
Table 2 presents a sample of the

revisions made to the student worksheet. Before revision, the task focused directly on applying a translation and reflection without clearly defining the initial geometric model or explicitly linking it to a cultural motif. After revision, the worksheet was improved by adding a clear description of the initial coordinates of the geometric figure, separating transformation steps more systematically, and explicitly asking students to explain the mathematical meaning of the transformation pattern in relation to batik motif repetition. These revisions were intended to support students' conceptual understanding, reduce cognitive ambiguity, and strengthen the ethnomathematical context of the task.

Implementation

Putting the design into practice, the Implementation stage involved 28 students who first completed a pretest, then engaged in group projects: identifying transformations in songket patterns, producing new digital motifs, and presenting their work while the instructor facilitated and reinforced key ideas. The activity of students' identifying transformations in songket patterns can be seen in Figure 3, students' worksheet PjBL result in Figure 4, students' GeoGebra result in Figure 5, and students' presentation can be seen in Figure 6.

Figure 3. Students' Identifying Transformation in Songket



2. Motif Naga Besaung
   - Deskripsi: Gambaran naga besar yang melambangkan kekuatan dan kejayaan.
   - Visual:
3. Motif Bungo Cengkeh
   - Deskripsi: Bentuk bunga cengkeh kecil yang melambangkan keharuman dan kesuburan.
   - Visual:
4. Motif Tampuk Manggis
   - Deskripsi: Bentuk menyerupai buah manggis yang terbuka, melambangkan isi hati yang jujur dan keterbukaan.
   - Visual:
5. Motif Bintang Berante
   - Deskripsi: Pola bintang yang saling terhubung, melambangkan harapan dan cita-cita tinggi.(Pinterest)
   - Visual:

Figure 4. Students' Worksheet PjBL Result

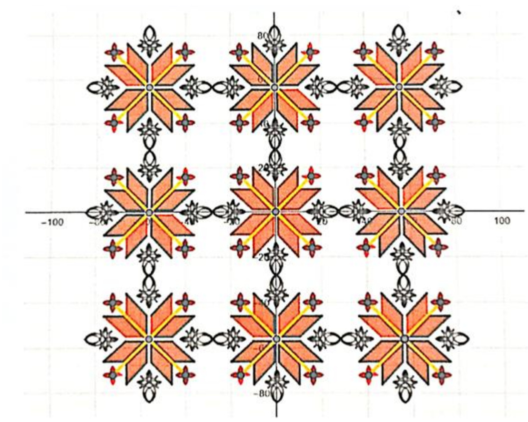


Figure 5. Students' GeoGebra Result

Figure 6. Students' Presentation

Evaluation

To determine impact and usability, the Evaluation stage combined ongoing formative observation and feedback with summative measures: post-tests of conceptual understanding, rubric-based product assessments, and student questionnaires on practicality. The practicality test result can be seen in Table 3.

Table 3. The Practicallity Result

No	Statement	Score
1	The procedures of the ethnomathematics-based PjBL model are readily comprehensible and straightforward to follow	3.60
2	The instructional media employed are difficult to navigate and may cause confusion	3.40
3	The instructor provides guidance that remains clear and consistently easy to follow throughout the session	3.70
4	The assigned project lacks alignment with, or relevance to, local cultural contexts	3.50
5	The learning activities effectively promote active discussion and collaboration within groups	3.80
6	The time allocated for completing the project is insufficient	3.30
7	The approach facilitates understanding of reflection, translation, rotation, and dilation	3.70
8	The model is associated with decreased motivation to engage in mathematics learning	3.60
9	The incorporation of local cultural elements enhances the perceived attractiveness and engagement of the material	3.90
10	The instructional model appears overly complex and challenging to implement	3.40

According to Table 3, the highest score appears on item 9 ("The incorporation of local cultural elements enhances the perceived attractiveness and engagement of the material"), with a mean of 3.90, indicating that the integration of ethnomathematical elements is highly appreciated by students. The lowest score occurs on item 6 ("The time allocated for completing the project is insufficient"), with a mean of 3.3, suggesting the need to adjust the project duration. Based on these results, the average total score of 3.49 falls within the "Highly Practical" category, meaning students perceived the ethnomathematics-based PjBL model as easy to understand, clearly instructed, supported by helpful media, and aligned with projects relevant to their lives.

Next, quantitative results were analyzed with a paired-samples t-test and Cohen's d, while qualitative responses were described to capture students' perceptions of the model's ease of use and relevance. Statistic descriptive for pretest and posttest can be seen in Figure 7. Effectiveness was tested using a paired-samples t-test with a 5% significance level ($\alpha = 0.05$). The results were as follows:

Mean score gain = 24.27

t Stat = 14.82

p-value = 0.000 (< 0.05)

The p-value indicate that there is a significant difference between the pretest and posttest scores.

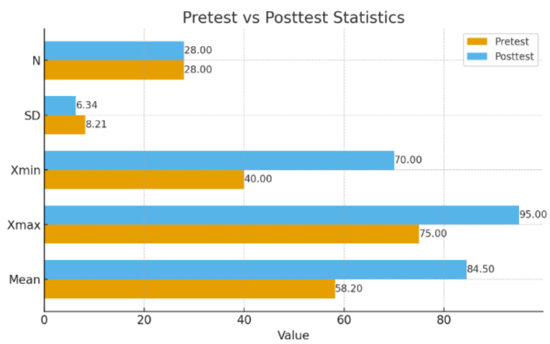
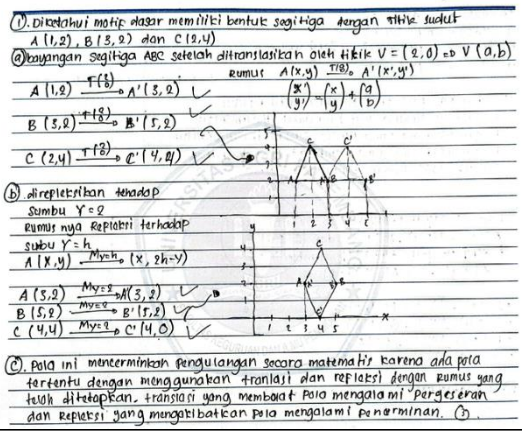


Figure 7. Statistic Descriptive

In addition, Cohen's d was 2.71, which indicates a very large effect. According to (Cohen et al., 2023), this value reflects a very strong impact of the model on students' learning outcomes. The significant score increase confirms that the ethnomathematics-based PjBL model is effective in enhancing students' understanding of geometric transformations. The example of students' solution for the test can be seen in Figure 8.



Students' solution in English version

1. It is known that the basic motif has a triangular shape with vertices
A (1, 2), B (3, 2), and C (2, 4).

a) Determine the image of triangle ABC after it is translated by the vector
v = (2, 0) or **v = (a, b)**.
The translation formula is:
If a point A(x, y) is translated by vector (a, b), then the image is A′(x + a, y + b).

- A (1, 2) → A′(3, 2)
- B (3, 2) → B′(5, 2)
- C (2, 4) → C′ (4, 4)

b) The translated figure is then reflected across the line **y = 2**.
The reflection formula across the line y = h is:
A(x, y) → A′(x, 2h – y)

- A′(3, 2) → A″ (3, 2)
- B′ (5, 2) → B″ (5, 2)
- C′ (4, 4) → C″ (4, 0)

c) This pattern represents repetition in mathematics because it follows a specific structure using translation and reflection with defined formulas. Translation causes the pattern to shift, while reflection causes the pattern to be mirrored.

Figure 8. Students' Solution for the Test

The student's written response shows how the ethnomathematics-based Project-Based Learning (PjBL) model supports meaningful understanding of transformation geometry. The student was able to correctly apply translation and reflection procedures and represent the results visually, indicating solid procedural understanding. More importantly, she attempted to explain the repetition of batik motifs using geometric transformations, which reflects emerging conceptual understanding. This suggests that learning activities grounded in cultural contexts helped the student connect abstract transformation concepts with familiar visual patterns. Through project-based exploration, discussion, and reflection, students did not only perform calculations but also interpreted transformations as part of a meaningful structure found in cultural artifacts. Although the explanation of cultural meaning could be further strengthened, the response demonstrates that the integration of PjBL and ethnomathematics facilitates a shift from purely procedural learning toward contextual and conceptually oriented understanding. This finding supports the role of ethnomathematics-based PjBL in enhancing students' reasoning, visualization, and interpretation of geometric transformations.

Discussion

The findings of this study do more than confirm that the ethnomathematics-based PjBL model is valid, effective, and practical; they provide insight into why this instructional integration produces substantial learning gains and how the learning process supports deep conceptual change in transformation geometry. Such outcomes align with design-research criteria that treat expert judgement on content accuracy, linguistic clarity, presentation, and graphical quality as primary indicators of product validity (Plomp & Nieveen, 2013).

They directly also respond to the dominance of abstract and procedural instruction in transformation geometry. Conventional instruction often fails to connect geometric concepts to meaningful contexts, resulting in weak conceptual understanding. Previous research indicates that integrating cultural context into mathematics learning can foster deeper comprehension and student engagement. For example, Syaripah (2025) found that students rated the integration of PjBL with ethnomathematics in a transformation geometry course as highly appropriate and beneficial for critical thinking. Meta-analytic evidence further supports the pedagogical value of ethnomathematics, showing that learning approaches grounded in cultural contexts have a strong positive effect on students' mathematical literacy compared to conventional methods (Pratama & Yelken, 2024).

The large effect size observed in the present study can be understood in light of these findings. According to recent benchmarks, effect sizes of this magnitude represent highly meaningful educational impact (Lakens, 2013). This connection likely explains the unusually large effect size, as students are not only learning new concepts but also reinterpreting familiar cultural patterns through a mathematical lens. As a result, learning becomes both cognitively demanding and personally meaningful, a combination that is rarely achieved in abstract geometry instruction (Simatupang & Siregar, 2023).

Models that embed cultural artifacts within project-based tasks appear to help students move beyond rote application of procedures toward meaningful conceptual understanding. Research on ethnomathematics-based problem learning also shows that students' conceptual understanding improves when mathematics tasks reflect real cultural contexts rather than abstract exercises (Bintoro et al., 2024). Similarly, Paramitha et al. (2024) reported that culturally grounded geometry frameworks improve students' ability to understand geometric concepts concretely.

Transformation geometry requires the coordination of visual, spatial, and symbolic representations. However, recent research shows that when these representations are introduced in isolation, students struggle to form coherent mental models (Luz & Yerushalmy, 2023). In contrast, the ethnomathematics-based PjBL model situates transformation concepts within culturally familiar artifacts, enabling students to interpret transformations as meaningful operations on concrete objects rather than as isolated formulas. This contextualization reduces abstraction barriers and supports deeper conceptual understanding.

Furthermore, integrating local cultural knowledge into PjBL activities also supports students' affective and motivational engagement. Ngala and Marsigit (2024) found that a PjBL approach based on local house ethnomathematics significantly enhanced students' creative thinking and mathematical disposition, indicating that cultural contexts make learning more meaningful. Additional evidence on PjBL alone suggests that project-oriented tasks help students connect abstract mathematics with real-world applications, thereby improving conceptual learning and 21st century skills (Siregar, 2024). Recent study also indicate that culturally responsive mathematics instruction enhances students' engagement and supports the development of mathematical meaning by connecting new concepts to familiar cultural experiences (Aslan-Tutak et al., 2021). In this study, cultural artifacts such as songket motifs functioned as cognitive anchors that helped students reinterpret familiar patterns through a mathematical lens, thereby explaining the unusually large learning gains.

Nevertheless, the challenges identified, such as time constraints and unequal access to cultural resources, suggest that the effectiveness of this model depends on careful instructional planning. Adequate project duration and the use of digital cultural repositories are necessary to sustain inquiry without overburdening students. Addressing these issues may further enhance the model's impact and scalability.

The results indicate that the large learning gains are not incidental but stem from a theoretically coherent integration of PjBL and ethnomathematics. By simultaneously addressing cognitive, affective, and contextual dimensions of learning, the model creates conditions that are particularly conducive to mastering transformation geometry. This explains not only that the model is effective, but why it is capable of producing educationally meaningful improvements at a high magnitude.

CONCLUSION

The ethnomathematics-based Project-Based Learning (PjBL) model for geometric transformations demonstrates a very high level of validity, practical for classroom implementation, and also effective in improving student learning outcomes. These findings imply that mathematics lecturers, particularly in mathematics education programs, can use ethnomathematics-based PjBL as an alternative instructional approach to address the limitations of abstract and procedural teaching in transformation geometry. Integrating local cultural artifacts into project activities provides meaningful contexts that support students' conceptual understanding, engagement, and cultural awareness. The model may also serve as a reference for curriculum developers in designing culturally responsive learning materials that align with student-centered and project-oriented pedagogy. This study contributes to the growing body of research on Project-Based Learning and ethnomathematics by demonstrating how their integration can produce substantial learning gains in higher education geometry courses. The findings support the view that culturally grounded project-based instruction can facilitate higher-order thinking and conceptual change by linking mathematical representations with students' lived experiences. Despite these positive findings, the results of this study should be interpreted with caution. The research was conducted within a single Mathematics Education program at one higher education institution, with a relatively small sample size and a one-group pretest–posttest design. Furthermore, the cultural context was limited to South Sumatran artifacts, particularly songket motifs, which may influence the transferability of the findings to different cultural or institutional settings. Therefore, while the model shows strong potential, its effectiveness cannot be assumed to generalize across diverse student populations, courses, or cultural contexts without further empirical testing. Future research may extend this work by comparing different cultural artifacts, examining variations in levels of cultural integration and task complexity, employing comparative or experimental designs, and investigating longer-term learning outcomes such as retention, transfer, and professional dispositions of prospective mathematics teachers.

REFERENCES

Albab, I. U., Hartono, Y., & Darmawijoyo, D. (2014). Kemajuan belajar siswa pada geometri transformasi menggunakan aktivitas refleksi geometri. *Jurnal Cakrawala Pendidikan*, *3*(3), 338–348. https://doi.org/10.21831/cp.v3i3.2378

Aslan-Tutak, F., Akay, H., & Ertaş, H. (2021). Cultural context in mathematics education: Effects on meaningful learning and cultural identity. *International Journal of Science and Mathematics Education*, *19*(5), 927–946. https://doi.org/10.1007/s10763-020-10091-3

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *83*(2), 39–43. https://doi.org/10.1080/00098650903505415

Bintoro, H. S., Aulya, R., & Wanabuliandari, S. (2024). The problem-based learning model assisted with the ethlaf application contains ethnomathematics to improve students' conceptual understanding capability. *Journal of Education Research and Evaluation*, *8*(1), 163–172.

Branch, R. M. (2009). *Instructional design: The ADDIE approach* (Vol. 722). Springer.

Cohen, L., Manion, L., & Morrison, K. (2023). *Research Methods in Education (9th ed.)*. Routledge.

Denuga, D. D., & Nkengbeza, D. (2022). Pre-service teachers experience in project-based learning approach: A case study of two campuses of the University of A (UNA). *Open Journal of Social Sciences*, *10*(04), 121–132. https://doi.org/10.4236/jss.2022.104009

dos Santos, E. F., Gonçalves, B. C. M., de Oliveira, K. B., & Silva, M. B. (2018). Project based learning applied to technical drawing. *Creative Education*, *09*(03), 479–496. https://doi.org/10.4236/ce.2018.93034

Dwirahayu, G., Satriawati, G., Putri, F. M., Hafiz, M., Kustiawati, D., & Sobiruddin, D. (2024). Enhancing mathematics pre-service teachers' pedagogical content knowledge through project-based learning. *Journal of Mathematics, Science and Technology Education*, *1*(2), 85–99.

Fauzi, A., & Setiawan, H. (2020). Etnomatematika: Konsep geometri pada kerajinan tradisional sasak dalam pembelajaran matematika di Sekolah Dasar. *Didaktis: Jurnal Pendidikan Dan Ilmu Pengetahuan*, *20*(2), 118–128. https://doi.org/10.30651/didaktis.v20i2.4690

Iskandar, R. S. F., Karjanto, N., Kusumah, Y. S., & Ihsan, I. R. (2022). *A systematic literature review on ethnomathematics in geometry*. https://arxiv.org/abs/2212.11788

Jeniver, Muhyiatul, F., & Heffi, A. (2023). Literatur review: Pengaruh model pembelajaran PJBL (project-based learning) terhadap keterampilan berpikir kritis peserta didik. *BIOCHEPHY: Journal of Science Education*, *03*(1), 10–20.

Jones, K. (2000). Providing a foundation for deductive reasoning. *Educational Studies in Mathematics*, *44*, 55–85. https://doi.org/https://doi.org/10.1023/A:1012789201736

Kandaga, T., Rosjanuardi, R., & Juandi, D. (2023). Analysis of cognitive obstacle in geometric transformation course on higher education. *The 8th International Conference on Mathematics, Science and Education 2021*, *2614*(1), 40070.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology*, *4*, 863. https://doi.org/10.3389/fpsyg.2013.00863

Luz, Y., & Yerushalmy, M. (2023). Computer-supported assessment of geometric exploration using variation theory. *Journal for Research in Mathematics Education*, *54*(2), 141–174.

Napfiah, S., & Sulistyorini, Y. (2021). Errors analysis in understanding transformation geometry through concept mapping. *International Journal of Research in Education*, *1*(1), 6–15.

Ngala, J. C., & Marsigit, M. (2024). Ethnomathematics walewangko house in project-based learning to enhancing students' creative thinking and mathematical disposition. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran, dan Pembelajaran*, *10*(4), 1584–1595.

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/19963777

Par, Y. B. S., & Prasetyo, D. A. B. (2024). Kajian etnomatematika pada ritus budaya roko molas poco. *Jurnal Inovasi Pendidikan Matematika*, *6*(2), 110–123.

Paramitha, N. K. D., Suarjana, I. M., & Jayanta, I. N. L. (2024). Ethnomathematics-based geometry framework to improve students metacognitive skills and mathematical understanding. *International Journal of Natural Science and Engineering*, *8*(3), 144–154.

Pathuddin, H., & Busrah, Z. (2024). Ethnomathematics: Learning geometric transformation through the formation of lagosi motif. *Jurnal VARIDIKA*, 155–173.

Plomp, T., & Nieveen, N. (2013). Educational design research. *Netherlands Institute for Curriculum Development: SLO*, 1–206.

Pratama, R. A., & Yelken, T. Y. (2024). Effectiveness of ethnomathematics-based learning on students' mathematical literacy: a meta-analysis study. *Discover Education*, *3*(1), 202.

Retno, R. S., Purnomo, P., Hidayat, A., & Mashfufah, A. (2025). Conceptual framework design for STEM-integrated project-based learning (PjBL-STEM) for elementary schools. *Asian Education and Development Studies*, *14*(3), 579–604.

Rosa, M., & Orey, D. (2016). Humanizing mathematics through ethnomodelling. *Journal of Humanistic Mathematics*, *6*(2), 3–22. https://doi.org/10.5642/jhummath.201602.03

Sari, R. M. ., Priatna, N., & Juandi, D. (2022). Implementing project-based blended learning model using cognitive conflict strategy to enhance students' mathematical spatial literacy. *European Journal of Educational Research*, *11*(4), 2031–2041. https://doi.org/https://doi.org/10.12973/eu-jer.11.4.2031

Savery, J. R., & Duffy, T. M. (2001). Problem based learning: An instructional model and its contructional framework. *Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae*. https://doi.org/10.13671/j.hjkxxb.2015.0637

Simatupang, M. L. D., & Siregar, H. B. (2023). Bahan ajar interaktif berbasis pendekatan PMRI untuk meningkatkan kemampuan pemecahan masalah matematis siswa SMP. *Blackboard Journal: Research Innovation In Mathematics Education*, *1*(1), 1–9.

Siregar, T. P. (2024). The effect of project-based learning method on understanding geometry concepts in secondary school students. *Attractive: Innovative Education Journal*, *6*(3), 302–310.

Sugiyono. (2015). *Metode Penelitian Pendidikan (Pendekatan Kuantitatif, Kualitatif dan R&D)*. Alfabeta.

Syaripah, S. (2025). Integrating ethnomathematics with project-based learning: student perceptions on the development of mathematical critical thinking skills in geometry. *AL-ISHLAH: Jurnal Pendidikan*, *17*(2).

Thomas, J. (2000). A review of research on Profect-Based Learning. In *International Geology Review* (Vol. 63, Issue 1, pp. 1–45). https://doi.org/10.1080/00206814.2019.1702592

Trisna, T. A., Ikhsan, M., & Elizar, E. (2022). Abilities and difficulties of ninth-grade students in solving geometry transformation problems. *Jurnal Pendidikan MIPA*, *23*(4), 1724–1737.

Yulianto, D., Junaedi, Y., Juniawan, E. A., & Anwar, S. (2024). Kemampuan berpikir tingkat tinggi siswa smp melalui pendekatan matematika realistik dengan model PBL dan CTL berbasis project-based learning pada penyelesaian soal AKM di Kabupaten Lebak Banten. *Teorema: Teori Dan Riset Matematika*, *9*(1), 57. https://doi.org/10.25157/teorema.v9i1.13457

Zulkardi. (2002). *Developing a Learning Environment on Realistic Mathematics Education for Indonesian Students Teachers*. University of Twente.