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

Nila Kesumawati[1*], Yunika Lestaria Ningsih[1], Dina Octaria[1], Rohana[1]

[1]Universitas PGRI Palembang

Correspondence should be addressed to Nila Kesumawati:
nilakesumawati@univpgri-palembang.ac.id

Abstract

This study was motivated by students' limited understanding of geometry—particularly transformation geometry—which is often seen as abstract and difficult. Conventional teaching methods, being mostly procedural and disconnected from real-life contexts, have contributed to this problem. To address it, this research integrates Project-Based Learning (PjBL) with ethnomathematics, linking mathematical ideas to cultural practices such as weaving, wood carving, and traditional architecture. While PjBL encourages active, collaborative learning through real-world projects, ethnomathematics helps students relate mathematics to familiar experiences. Using the ADDIE framework—Analysis, Design, Development, Implementation, and Evaluation—this R&D study was conducted at a higher education institution in South Sumatra. Data were collected through tests, validation sheets, observations, and questionnaires. The results show that the ethnomathematics-based PjBL model is valid, practical, and effective in improving students' understanding of transformation geometry.

Keywords: Ethnomatematics; PjBL; Geometric Transformations

Abstrak

Penelitian ini dilatarbelakangi oleh keterbatasan pemahaman siswa terhadap geometri—khususnya geometri transformasi—yang sering dianggap abstrak dan sulit dipahami. Metode pembelajaran konvensional yang bersifat prosedural dan kurang terhubung dengan konteks kehidupan nyata turut memperburuk masalah ini. Untuk mengatasinya, penelitian ini mengintegrasikan Project-Based Learning (PjBL) dengan etnomatematika, yang mengaitkan konsep matematika dengan praktik budaya seperti menenun, mengukir kayu, dan arsitektur tradisional. PjBL mendorong pembelajaran aktif dan kolaboratif melalui proyek nyata, sedangkan etnomatematika membantu siswa memahami matematika melalui pengalaman yang akrab dan bermakna. Dengan menggunakan kerangka ADDIE—Analisis, Desain, Pengembangan, Implementasi, dan Evaluasi—penelitian R&D ini dilakukan di salah satu perguruan tinggi di Sumatera Selatan. Data dikumpulkan melalui tes, lembar validasi, observasi, dan angket. Hasil penelitian menunjukkan bahwa model PjBL berbasis etnomatematika valid, praktis, dan efektif dalam meningkatkan pemahaman siswa terhadap geometri transformasi.

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NIla Kesumawati: SCOPUS ID: 57205392929 | ORCID ID: 0000-0003-4796-6876
Yunika Lestaria Ningsih: SCOPUS ID: 57200722069 | ORCID ID: 0000-0001-5596-880X
Dina Octaria:SCOPUS ID: 57193350308 | ORCID ID: 0000-0003-0733-1550
Rohana: SCOPUS ID: 57221974943 | ORCID ID: 0000-0002-5589-7746

INTRODUCTION

Mathematics is globally recognized as a core subject essential for developing critical thinking, problem-solving abilities, and numerical literacy (OEDC, 2019). Within mathematics, geometry plays a pivotal role in cultivating spatial visualization skills and conceptual understanding, particularly in real-world and digital technology contexts. However, international assessments, such as the Programme for International Student Assessment (PISA), consistently reveal that students' performance in space and shape problem-solving remains relatively low across many countries, including Indonesia (OECD, 2023).

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 is among the topics students often find conceptually challenging. Mastery requires spatial visualization, an understanding of relationships between objects, and the application of transformation concepts—translation, reflection, rotation, and dilation (Jones, 2000; Sari et al., 2022). Many students struggle because instruction remains procedural and decontextualized (Zulkardi, 2002).

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, 2022b). However, there is limited research explicitly integrating ethnomathematics within a PjBL framework, particularly in teaching transformation geometry.

This study addresses this gap by developing an ethnomathematics-based PjBL model that incorporates local cultural contexts into mathematical project work. By engaging in culturally grounded, authentic projects, students explore transformation geometry through cultural objects such as symmetrical batik, woven patterns, and traditional architecture, while collaboratively constructing knowledge. This integration not only enhances cognitive understanding but also strengthens students' cultural identity and appreciation.

Project-Based Learning (PjBL) encourages students to engage in authentic projects that involve exploration, collaboration, and problem-solving (Bell, 2010; Thomas, 2000)(Bell, 2010; Thomas, 2000). In the context of mathematics education, PjBL has been empirically shown to enhance conceptual understanding and foster higher-order thinking skills (Jeniver et al., 2023; Yulianto et al., 2024).

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 (Bustan et al., 2021). Consequently, understanding of transformation concepts is enhanced not only cognitively but also through the reinforcement of cultural identity and appreciation of local heritage. Through this study, it is expected that an ethnomathematics-based PjBL model for teaching transformation geometry will be designed to provide effective and innovative learning strategies that can be implemented by lecturers, thereby enabling students to achieve the expected competencies and to become high-quality mathematics educators in the future.

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: We identified students' learning needs and challenges, noting persistent difficulty with reflection, rotation, translation, and dilation when taught abstractly and without real-life context. We reviewed learner characteristics and prior knowledge, then analyzed content (basic competencies and indicators) and cultural context through direct observation of South Sumatran songket motifs that display 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 (RPP), student worksheets (LKPD), 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: We produced materials and media and built project assessments. Three experts validated content, language, presentation, and graphics, after which we revised and piloted the materials with 6–8 students.

Implementation: In a class of 28, students took a pretest, then—guided by the lecturer—analyzed songket patterns, created digital motif designs, and presented results. Finally in Evaluation: Formative observation and feedback ran throughout. Summative measures included a posttest, rubric-based product scoring, and a student questionnaire. We used paired-samples t-tests and Cohen's d for effectiveness, and descriptive analysis for perceptions.

RESULTS AND DISCUSSION

Results

5

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.

Beginning with the Analysis stage, the team identified why students struggled with geometric transformations when taught abstractly, then argued for grounding learning in authentic contexts. They profiled learners who were familiar with local cultural motifs—such as songket and traditional carvings—yet unaware that these embodied reflection, rotation, translation, and dilation. This led them to map the essential competencies and to document South Sumatran songket motifs that display repetition, symmetry, rotation, and scaling. From there, they specified a culture-based project requiring at least three transformations and inventoried resources, including motif photos, GeoGebra, and access to local artisans.

Building on this needs analysis, the Design stage translated insights into concrete learning goals and materials. Content on reflection, rotation, translation, and dilation was integrated with songket exemplars and framed by an essential question—"How can transformation patterns in songket be developed into a new, aesthetically pleasing and mathematically sound motif?" Learning activities progressed from observing and analyzing motifs to creating digital designs and presenting results. The team prepared an LKPD to scaffold discovery, devised media and tools, and constructed rubrics that emphasized conceptual accuracy, creativity, cultural relevance, and collaboration, followed by a reflective discussion linking mathematics to cultural preservation.

With the blueprint in place, the Development stage turned the design into usable products: RPP, LKPD, media (photos, sketches, GeoGebra simulations), and assessment instruments. Expert validators in mathematics, PjBL, and ethnomathematics reviewed content, language, presentation, and graphics, prompting revisions that sharpened instructions, accuracy, and visuals. The validity test result can be seen in Figure 1.

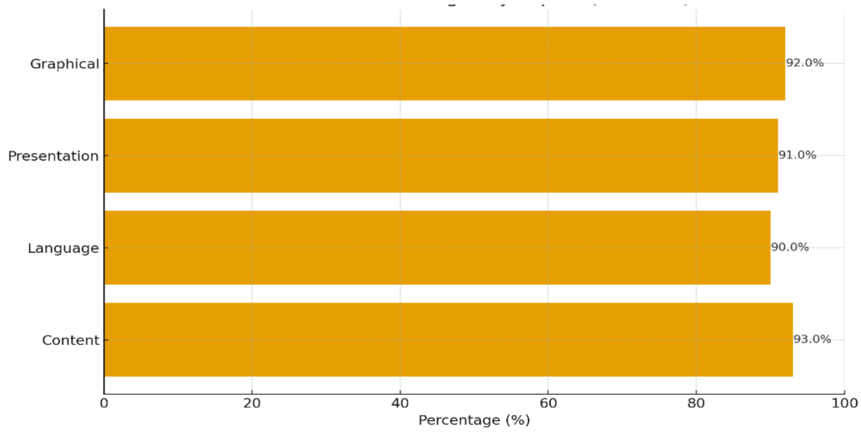
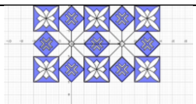


Figure 1. The Validity Test Result

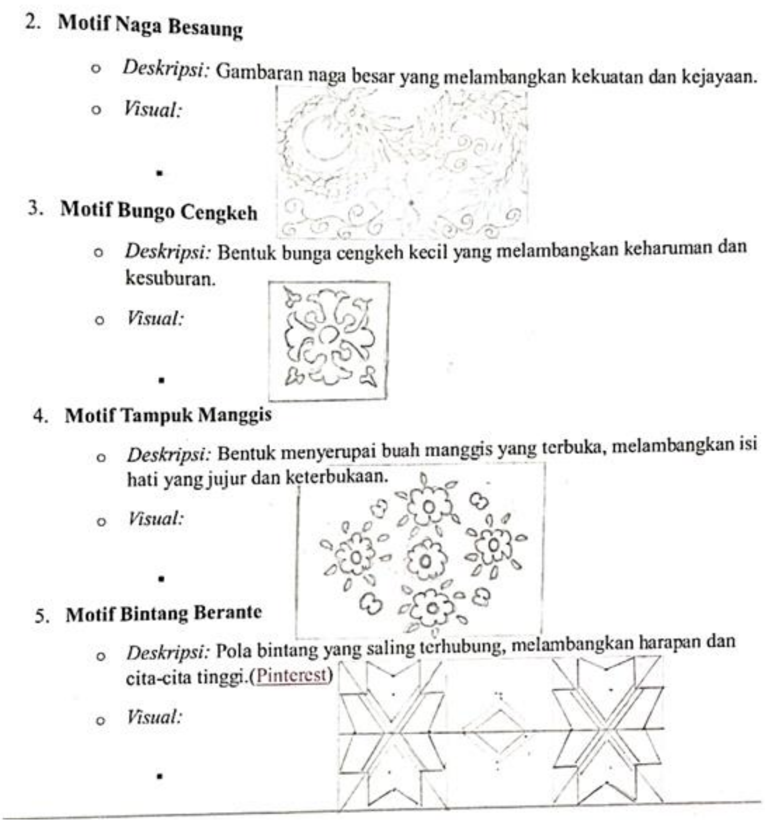
According to Figure 1, the developed ethnomathematics-based Project-Based Learning (PjBL) model was declared highly feasible for use in classroom instruction. The validation results indicate that the model is appropriate in terms of content, language, presentation, and graphical aspects, making it suitable for implementation in mathematics learning. Before and after revision of the worksheet in this stage can be seen in Table 1.

Table 1. 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.

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 2, students' worksheet PjBL result in Figure 3, students' GeoGebra result in Figure 4, and students' presentation can be seen in Figure 5.

Figure 2. 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 3. Students' Worksheet Pjbl Result

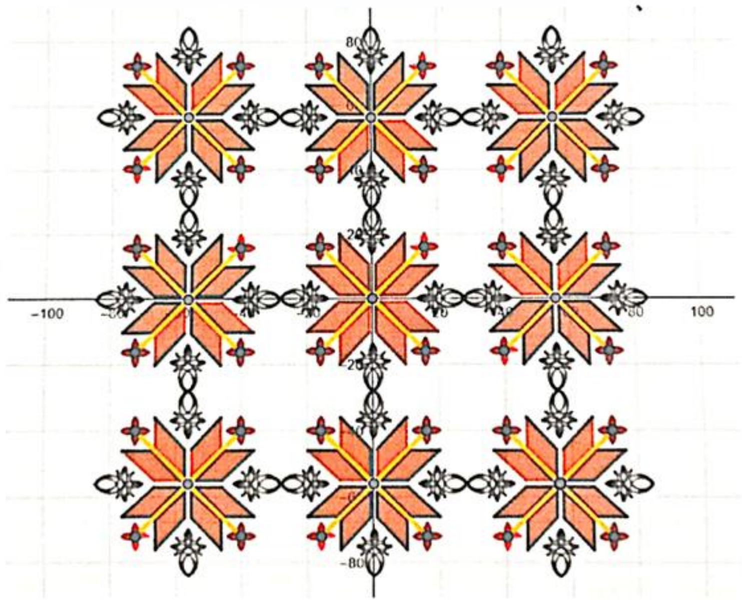


Figure 4. Students' GeoGebra Result

Figure 5. Students' Presentation

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 2.

Table 2. 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 2, 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 6. 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.

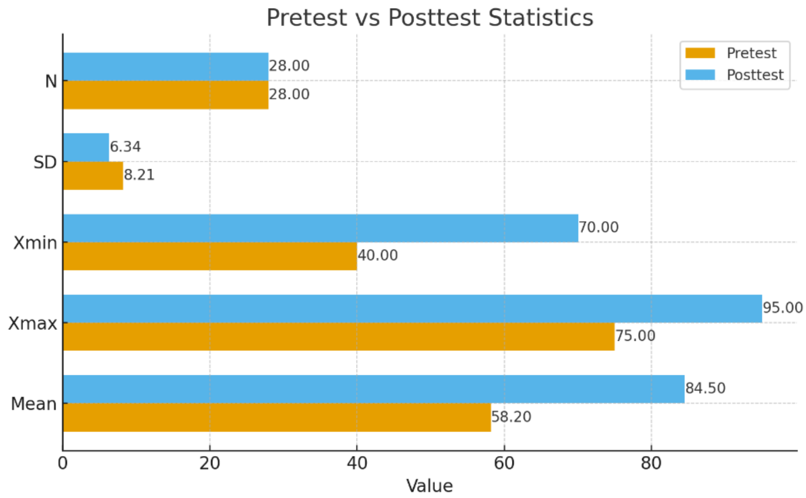


Figure 6. Statistic Descriptive

In addition, Cohen's d = 2.71 (very large effect), indicating that the model produced a substantial improvement in 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 7.

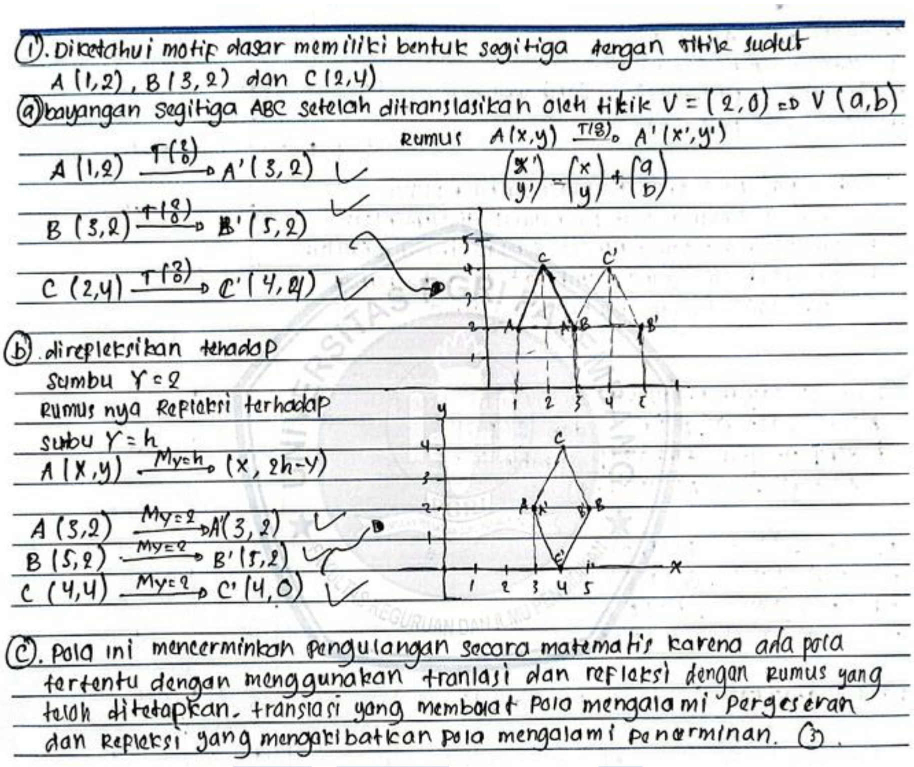


Figure 7. Students' Solution for the Test

Discussion

The present study provides converging evidence that an ethnomathematics-based Project-Based Learning (PjBL) model for geometric transformations is valid, effective, and practical for classroom implementation. First, expert appraisals across content and media yielded a high mean validation score (4.58; "very valid"), indicating sufficiency for instructional use without substantive revision.

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).

Second, the model's effectiveness is supported by a statistically significant pretest–posttest gain ($p < .05$) and a very large effect size (Cohen's $d = 2.71$). Benchmarks for standardized mean differences suggest that effects of this magnitude represent educationally meaningful improvement (Lakens, 2013; Sullivan & Feinn, 2012). The observed gains are theoretically consistent with prior work showing that PjBL cultivates deeper conceptual understanding when learners engage in authentic, sustained inquiry and knowledge construction (Bell, 2010; Thomas, 2000).

Third, evidence of practicality—high student ratings (mean = 34.87; "highly practical") and positive instructor feedback—indicates ease in planning, facilitation, and assessment, which are central usability criteria in educational design research (Plomp & Nieveen, 2013). Notably, embedding tasks in local cultural practices (e.g., songket motifs) appears to heighten engagement while preserving conceptual rigor, echoing literature that ethnomathematical contexts humanize mathematics and strengthen students' connections to ideas through culturally situated modeling (Rosa & Orey, 2016). This research also reinforces the findings of Simatupang and Siregar (2023), which revealed that the use of traditional fabric motifs as learning media for geometry enhances students' spatial visualization and emotional connection to the subject matter.

However, some challenges were also identified: a. Time management: Several students felt that the project duration was relatively short, particularly for the stages of collecting cultural data and visualizing the transformations. b. Availability of local cultural resources: Students who lived far from cultural sources required additional strategies, such as utilizing digital documentation.

Furthermore, the finding that students highly appreciated the use of local culture is consistent with the study by Aslan-Tutak et al. (2021), which reported that contextualizing mathematics learning with cultural elements fosters meaningful learning and strengthens students' cultural identity. Denuga and Nkengbeza (2022a), also emphasized that the success of PjBL is highly influenced by the clarity of instructions, the availability of learning media, and the relevance of projects to students' real-life contexts. Thus, the integration of PjBL and ethnomathematics in this study not only contributes to cognitive improvement but also builds students' cultural awareness.

CONCLUSION

The ethnomathematics-based Project-Based Learning (PjBL) model for geometric transformations (reflection, translation, rotation, and dilation) demonstrates a very high level of validity. This is evidenced by expert evaluations of content and media, yielding an average validation score of 4.58 ("very valid"), indicating that the model is suitable for use without substantial revision.

The model is effective in improving student learning outcomes, as shown by a significant difference between pretest and posttest scores ($p < 0.05$) and an effect size of 2.71 (very large). These results indicate a strong impact on mastery of geometric transformation concepts. It is practical for classroom implementation, supported by student response questionnaires showing an average score of 34.87 ("highly practical") and lecturer feedback indicating ease in planning, delivery, and evaluation.

In sum, situating PjBL within ethnomathematical contexts offers a culturally responsive and instructionally robust pathway for teaching reflection, translation, rotation, and dilation. Future work might (a) compare alternative cultural artifacts and degrees of cultural integration, (b) examine dosage and task complexity as moderators of impact, and (c) track longer-term outcomes (retention, transfer, dispositions) alongside achievement and motivation

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