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Development of Deep Learning-Based Ethnomathematics E-LKPD to Improve Mathematical Creative Thinking

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Abstract

This study aimed to develop an ethnomathematics-based electronic student worksheet (E-LKPD) integrated with a deep learning approach emphasizing meaningful learning, mindful learning, and joyful learning to improve ninth-grade students' mathematical creative thinking skills in transformation geometry. The novelty of this study lies in the integration of ethnomathematical contexts and deep learning principles into an electronic worksheet designed to foster students' mathematical creative thinking skills. This study employed a Research and Development (R&D) method using the 4D model, consisting of the define, design, develop, and disseminate stages. The participants were 35 ninth-grade students of Putra Harapan Boarding School Purwokerto, comprising 17 students in the experimental class and 18 students in the control class. Data were collected through expert validation sheets, student response questionnaires, and open-ended essay tests of mathematical creative thinking skills. The developed E-LKPD was categorized as highly valid and highly practical. The effectiveness analysis revealed a significant difference between the experimental and control groups (Mann–Whitney U = 93.00; p = 0.046), with an effect size of 0.337, indicating a moderate effect on students' mathematical creative thinking skills. The findings indicate that the developed E-LKPD is feasible and effective as an innovative instructional material. It can serve as an alternative digital learning resource that integrates local culture with meaningful mathematics learning while enhancing students' mathematical creative thinking skills.

Keywords: ethnomathematics, mathematical creative thinking skills, meaningful learning, digital learning materials, geometry transformation

1. INTRODUCTION

Along with the development of 21st-century education, learning is no longer focused solely on the mastery of knowledge, but also emphasizes the development of higher-order thinking skills, including critical, creative, collaborative, and communicative thinking skills. These competencies are essential to equip students in facing increasingly complex global challenges and adapting to dynamic situations (Thornhill-Miller et al., 2023). Among these competencies, creative thinking skills receive particular attention because they enable students to generate innovative ideas, explore various alternative solutions, and adapt flexibly to new situations.

In mathematics education, creative thinking skills are particularly important because students are not only required to apply procedures but also to construct various strategies and solutions in solving mathematical problems. Research shows that creative thinking skills are influenced by cognitive and affective factors, such as growth mindset and self-confidence in generating creative ideas (Zhao et al., 2021). Therefore, mathematical creative thinking can be considered an important indicator of successful mathematics learning, as it reflects not only learning outcomes but also the quality of students' thinking processes.

Mathematical creative thinking is generally reflected in four dimensions, namely fluency, flexibility, originality, and elaboration. Fluency refers to the ability to generate many relevant ideas or solutions; flexibility is related to the ability to use various strategies in solving problems; originality indicates the ability to produce unique and uncommon ideas; while elaboration refers to the ability to develop ideas in detail and depth. These four dimensions serve as an important framework for assessing students' mathematical creative thinking skills in learning activities (Putri et al., 2022).

However, this ideal condition has not yet been fully realized in classroom practice, as mathematics learning is still dominated by procedural approaches and routine exercises. Such learning patterns tend to position students as passive recipients of information and provide limited opportunities for independent exploration of ideas. Research by Majidi et al. (2025). shows that students with low mathematical ability are only able to understand problems at the initial stage, experience difficulties in applying concepts, and face obstacles in reasoning and communicating solutions systematically. Meanwhile, students with moderate ability are generally able to understand and solve problems but have not demonstrated adequate ability to generalize concepts appropriately. In addition, Susanti and Novtiar (2022) reported that the mathematical creative thinking skills of junior high school students in Karawang Regency are still in the low category, particularly in the aspects of fluency, flexibility, originality, and elaboration.

Similar findings were also obtained in the context of this study. Previous research conducted at the same school showed that students' mathematical creative thinking skills were still dominated by the low category, with 70% of students in the very low category and 17% in the low category, while only 12% reached the sufficient to very good category (Fitriyani et al., 2024). These findings indicate that students still experience difficulties in generating diverse ideas and solution strategies when solving mathematical problems. Overall, these research results suggest that the development of mathematical creative thinking skills has not been optimally facilitated and highlight the need for innovation in teaching materials specifically designed to stimulate creativity indicators and systematically develop students' mathematical creative thinking skills.

One form of instructional innovation that can address this problem is the Electronic Student Worksheet (E-LKPD). E-LKPD is a digital adaptation of conventional student worksheets that integrates multimedia elements such as text, images, animations, and interactive features into a single learning platform. Previous studies show that interactive E-LKPD can improve the quality of learning by presenting more engaging materials and facilitating active student participation (Herawati & Muhtadi, 2021).

In addition, digital technology can help visualize abstract mathematical concepts, making them more concrete and easier for students to understand (Wang & Li, 2024). Beyond its technological advantages, E-LKPD also has the potential to support the development of mathematical creative thinking skills. Through interactive activities, contextual problems, and open-ended tasks, E-LKPD can encourage students to generate various solution strategies, explore alternative ideas, and develop mathematical concepts more deeply. Such learning experiences provide students with opportunities to develop fluency, flexibility, originality, and elaboration as important dimensions of mathematical creativity (Zhao et al., 2021).

To provide meaningful learning experiences, ethnomathematics can be integrated into mathematics learning by connecting mathematical concepts with local cultural practices. Ethnomathematics enables students to learn mathematics through contexts that are close to their daily lives, thereby improving conceptual understanding while fostering appreciation of culture (Bimantara, 2024).

Previous research shows that cultural artifacts contain various mathematical concepts that can be explored in classroom learning, including geometric transformation concepts found in traditional cultural products (Abbas et al., 2024). More importantly, cultural contexts provide opportunities for students to observe patterns, interpret mathematical ideas from different perspectives, and construct various solution strategies.

Such learning experiences can encourage students to generate diverse mathematical ideas and representations, which are closely related to the development of mathematical creative thinking skills. Therefore, ethnomathematics not only has the potential to improve conceptual understanding but also to foster students' mathematical creativity.

Several studies have reported that ethnomathematics-based teaching materials are feasible and beneficial in mathematics learning. Ainiyah & Loviana (2024) found that ethnomathematics-based student worksheets on transformation topics were categorized as highly valid and practical. Similarly, Liesandra and Nurafni (2022) reported that ethnomathematics-based E-LKPD in geometry learning was valid in terms of both content and media aspects.

Based on these findings, this study uses the Putra Harapan batik as an ethnomathematical context because its motifs contain geometric patterns representing several transformation concepts, such as translation, reflection, and rotation. The arrangement of repeated motifs allows students to observe mathematical relationships embedded in authentic cultural artifacts.

Although dilation patterns are not explicitly found in the original motifs, the same batik pattern can be proportionally enlarged or reduced in learning activities to help students understand the concept of dilation. By integrating cultural elements and mathematical concepts, learning becomes more contextual, meaningful, and relevant to students' experiences.

In addition to ethnomathematics, this study integrates a deep learning approach to support the development of students' mathematical creative thinking skills. In the educational context, deep learning does not refer to artificial intelligence technology, but rather to a learning approach that emphasizes meaningful understanding, active knowledge construction, reflection, and the connection of learning experiences with real-life contexts (Abbas et al., 2024).

Deep learning encourages students to engage cognitively and affectively in the learning process through meaningful, mindful, and joyful learning experiences. This approach has been reported to enhance students' motivation, engagement, and learning outcomes through active participation and deeper conceptual understanding Hamidah et al. (2025).

In the developed E-LKPD, deep learning principles are implemented through activities that encourage students to observe, analyze, reflect, create, and communicate mathematical ideas by utilizing cultural contexts and digital media.

Previous studies have reported the development of ethnomathematics-based worksheets and E-LKPD that are proven to be valid and practical for mathematics learning (Ainiyah & Loviana, 2024; Liesandra and Nurafni, 2022).Other studies have also highlighted the pedagogical potential of deep learning in promoting meaningful and active learning experiences (Akmal et al., 2025; Hamidah et al. 2025).

However, limited attention has been given to the integration of ethnomathematics and deep learning principles in the form of E-LKPD specifically designed to develop students' mathematical creative thinking skills in transformation geometry. In addition, the use of local cultural contexts such as the Putra Harapan batik motif as a medium for exploring geometric transformation concepts has also not been widely studied.

Therefore, there is a need to develop innovative learning tools that combine cultural relevance, digital learning resources, and deep learning principles to support the development of students' mathematical creative thinking skills.

The novelty of this study lies in three aspects. First, it integrates ethnomathematics and deep learning principles meaningful, mindful, and joyful learning into an Electronic Student Worksheet (E-LKPD). Second, it utilizes the Putra Harapan batik motif, which represents the cultural identity of the Putra Harapan Islamic Boarding School and contains patterns related to geometric transformations, including translation, reflection, rotation, and dilation. Third, the developed E-LKPD is specifically designed to foster students' mathematical creative thinking skills through contextual, open-ended, exploratory, and project-based learning activities.

Based on these considerations, this study aims to develop an ethnomathematics-based

E-LKPD integrated with a deep learning approach and to examine its validity, practicality, and effectiveness in improving students' mathematical creative thinking skills in transformation geometry.

Theoretically, this study contributes to the development of a learning framework that integrates ethnomathematics and deep learning principles to support the enhancement of mathematical creative thinking skills. It also enriches the literature on culturally responsive mathematics education by demonstrating how local cultural contexts can be systematically integrated into digital teaching materials.

Practically, this study produces a valid, practical, and effective E-LKPD that can be used by mathematics teachers as an innovative learning resource for transformation geometry. The developed product is expected to support meaningful learning experiences, strengthen students' appreciation of local culture, and facilitate the development of mathematical creative thinking skills required in 21st-century education.

2. RESEARCH METHOD

This study employed a Research and Development (R&D) approach to develop an ethnomathematics-based E-LKPD integrated with a deep learning approach on transformation geometry for grade IX students. The development model used was the 4D model (Define, Design, Develop, and Disseminate) proposed by Thiagarajan et al. (1974), which provides a systematic and structured procedure for developing instructional materials (Sugiyono, 2019)

In addition, a quasi-experimental design was applied to examine the effectiveness of the developed product by comparing post-test results between the experimental class and the control class (Field, 2013).

This study was conducted at SMP Boarding School Putra Harapan Purwokerto in the 2025/2026 academic year. The participants consisted of grade IX students, comprising one experimental class (17 students) and one control class (18 students), selected using purposive sampling based on equivalent academic ability (Sugiyono, 2019). In addition, a small group trial involving 8 students with varying academic abilities (high, medium, and low) was conducted during the development process. Different groups of participants were involved at each stage in accordance with the objectives of each development phase.

The development procedure followed the 4D model. The define stage was carried out through observations and interviews to identify learning needs and students' mathematical creative thinking skills. The findings indicated that learning was still teacher-centered and students' creative thinking skills were still low, particularly in generating ideas, developing solution strategies, and communicating mathematical reasoning.

In the design stage, the E-LKPD was developed based on the Project-Based Learning (PBL) model by integrating ethnomathematics and deep learning principles. PBL supports active learning through real-world problem solving and product creation. Ethnomathematics was integrated through Batik Putra Harapan motifs as a contextual representation of transformation geometry, including translation, reflection, rotation, and dilation. Deep learning principles were implemented through meaningful, mindful, and joyful learning activities.

The develop stage aimed to produce a valid and practical learning product through expert validation, revision, and a small group trial. The product was validated by experts using a 4-point Likert scale, which is commonly used in educational research to measure perceptions and responses (Sugiyono, 2019). The reliability of the questionnaire was tested using Cronbach's Alpha, resulting in a value of 0.897, indicating high reliability.

Data analysis was conducted in three stages: validity, practicality, and effectiveness analysis. Validity and practicality were analyzed using mean scores based on the Likert scale. Effectiveness was analyzed by comparing post-test results between the experimental and control groups. Prior to hypothesis testing, a normality test was conducted. Since the data were not normally distributed, the Mann–Whitney U test was used to determine differences between the two groups Field (2013). In addition, effect size was calculated using the formula $r = Z/\sqrt{N}$ to determine the magnitude of the effect. The interpretation of effect size followed Cohen's criteria, namely 0.1 (small effect), 0.3 (medium effect), and 0.5 (large effect) (Cohen, 1988.; Field, 2013).

3. RESULTS

3.1 Development Result Based on the 4D Model

The development of an ethnomathematics-based E-Student Worksheet (E-LKPD) integrated with a deep learning approach was conducted using the 4D model, which consists of four stages: define, design, develop, and disseminate.

In the define stage, observations and informal interviews were conducted with ninth-grade students to identify learning needs related to transformation geometry. The findings indicated that mathematics learning was still dominated by teacher-centered instruction, students experienced difficulties in understanding the concepts of transformation geometry, digital learning media were limited, and students' creative thinking skills in mathematics were still low. These findings served as the basis for developing the E-LKPD integrating ethnomathematics and deep learning principles.

In the design stage, the E-LKPD was designed by integrating ethnomathematics in the form of Batik Putra Harapan motifs into the topic of transformation geometry, including translation, reflection, rotation, and dilation. The product was designed to facilitate meaningful, mindful, and joyful learning through activities such as observation, exploration, discussion, reflection, and project-based tasks. At this stage, research instruments were also developed, including validation sheets, student response questionnaires, and mathematical creative thinking tests.

(a) **(b)** **(c)** **(d)**

Figure 1. Main Features of the Developed E-LKPD

Figure 1(a) Cover page integrating Batik Putra Harapan motifs; 1(b) meaningful learning activities through batik observation; 1(c) mindful learning activities through discussion and reflection; and 1(d) project activities involving the creation of batik motifs based on geometric transformations. Figure 1 presents the main features of the developed E-LKPD.

The product integrates an ethnomathematical context derived from Batik Putra Harapan motifs and incorporates learning activities that are meaningful, mindful, and joyful. Students are guided to observe cultural patterns, discuss transformation strategies, reflect on their learning processes, and create original batik designs using concepts of geometric transformations. Through these activities, the E-LKPD is expected to facilitate students' mathematical creative thinking skills while connecting mathematical concepts with local cultural values.

The development stage was carried out through expert validation and product revision. The initial validation results revealed several weaknesses in terms of content completeness, learning sequence, creative thinking activities, navigation features, and clarity of instructions. Based on the validators' suggestions, revisions were made by enriching the geometry transformation content, strengthening open-ended and project-based activities, improving navigation features, and refining learning instructions. The revised product was then re-validated and obtained a "very valid" category.

The dissemination stage was conducted through classroom implementation and dissemination activities involving school management and mathematics teachers. The developed E-LKPD was introduced as an alternative digital learning resource that integrates local cultural context and deep learning principles in mathematics instruction.

3.2 Product Validity

The validity of the developed E-LKPD was assessed by mathematics education experts, covering aspects of content, media, and language. The validation was conducted in two stages. The first stage aimed to identify weaknesses in the initial product, while the second stage was carried out after revisions based on the validators' feedback.

Table 1.
Comparison of E-LKPD Validity Scores in Stage I and Stage II

Aspect	**Stage I**	**Category**	**Stage II**	**Category**
Content	2.12	Fair	3.65	Very Good
Media	1.57	Fair	3.71	Very Good
Language	2.33	Fair	4.00	Very Good
Average	**2.03**	**Fair**	**3.78**	**Very Good**

Based on Table 1, all validity aspects showed a significant improvement after the revision process. In the content aspect, the score increased from 2.12 to 3.65, indicating improvements in the completeness, depth, and systematic organization of the transformation geometry material. The media aspect showed the greatest improvement, increasing from 1.57 to 3.71, reflecting enhancements in navigation, accessibility, and supporting digital features. The language aspect also improved from 2.33 to 4.00 after revisions were made to improve clarity and instructional wording. Overall, the average validity score increased from 2.03 (fair) to 3.78 (very good), indicating that the developed E-LKPD meets the criteria of a highly valid instructional product.

Table 2.
Main Revisions Based on Validators' Recommendations

Aspect	**Validator's Recommendation**	**Revisions Made**
Content	Material was still incomplete and limited	Addition of transformation geometry materials and activities
Learning Activities	Creative thinking activities were still superficial	Addition of open-ended and project-based tasks
Learning Sequence	The learning flow was not yet systematic	Reorganization of activities from concepts to application
Media	Navigation and accessibility were still limited	Improvement of navigation features and usage instructions
Language	Instructions were incomplete and unclear	Revision and refinement of learning instructions

The validators' feedback mainly emphasized the improvement of content completeness, strengthening of creative thinking activities, enhancement of navigation features, and clarification of instructions. All recommendations were integrated into the revised product, resulting in significant improvements across all aspects of validity.

3.3 Product Practicality

The practicality of the developed E-LKPD was evaluated through a limited trial involving eight ninth-grade students. After using the E-LKPD, students completed a response questionnaire to assess the practicality of the product.

Table 3.
Practicality Results of the Developed E-LKPD

Assessment	**Score**	**Category**
Overall practicality	3.38	Very Practical

The practicality assessment results indicate that the developed E-LKPD obtained an average score of 3.38, which falls into the “very practical” category. This finding shows that students were able to use the E-LKPD effectively during the learning process and experienced only minor difficulties in accessing and completing the learning activities provided.

Student response analysis revealed several factors supporting the practicality of the E-LKPD. Students reported that the instructions were clear and easy to follow, the digital format was attractive and easily accessible, and the learning activities helped them understand the concept of transformation geometry more easily. Some students also stated that the integration of batik context and project-based activities made learning more engaging and enjoyable.

Although the practicality level was very high, some minor difficulties were reported during implementation. The most frequently mentioned issues were unstable internet connection, limited screen size when accessing the E-LKPD on mobile devices, and the need to read some instructions more carefully. However, these issues did not significantly hinder the overall learning process.

3.4 Product Effectiveness

The effectiveness of the developed E-LKPD was evaluated by comparing students' mathematical creative thinking abilities between the experimental class and the control class. Students in the experimental class learned using an ethnomathematics-based E-LKPD integrated with a deep learning approach, while students in the control class received conventional instruction.

Table 4.
Comparison of Posttest Scores

Class	Number of Students	Mean Score
Experimental	17	28.50
Control	18	19.10

Based on Table 4, the experimental class achieved a higher posttest mean score (28.50) compared to the control class (19.10). This indicates that students' mathematical creative thinking ability who learned using the developed E-LKPD was better than those who experienced conventional learning.

Table 5.
Results of the Mann–Whitney U Test

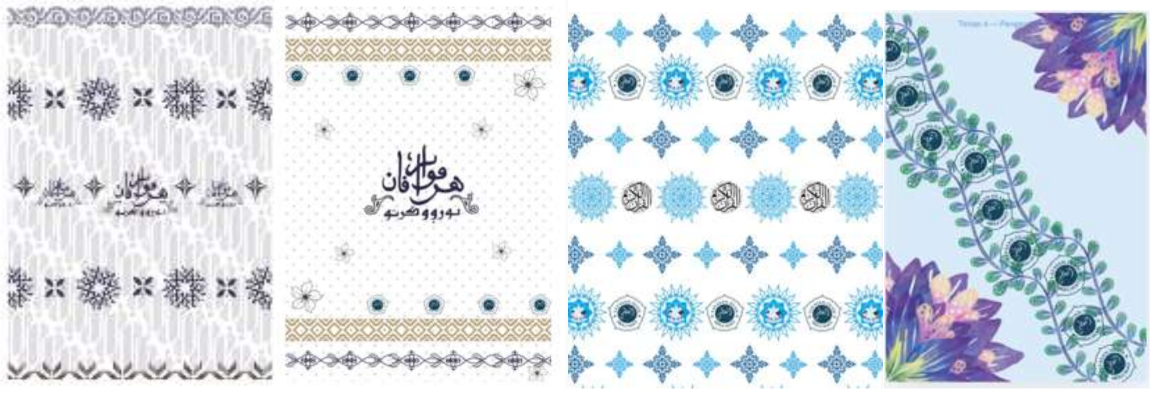
Statistic	Value
Mann–Whitney U	93.00
Z	-1.996
Sig. (2-tailed)	0.046
Effect Size (r)	0.337

The results of the Mann–Whitney U test show a significance value of 0.046, which is lower than 0.05. Therefore, there is a significant difference in mathematical creative thinking scores between students in the experimental class and those in the control class. In addition, the effect size value of 0.337 indicates a medium effect, suggesting that the developed E-LKPD provides a moderate contribution to improving students' mathematical creative thinking skills. Furthermore, to obtain a more detailed overview of students' mathematical creative thinking abilities, the posttest scores were analyzed based on four creativity indicators, namely fluency, flexibility, originality, and elaboration.

Table 6.
Mean Scores and Differences in Mathematical Creative Thinking Indicators

Indicator	Experimental Class	Control Class	Difference
Fluency	2.76	2.50	0.26
Flexibility	2.71	0.78	1.93
Originality	2.59	1.94	0.65
Elaboration	1.12	0.89	0.23

Based on Table 6, the experimental class obtained higher mean scores than the control class across all indicators of mathematical creative thinking.The largest difference was found in the flexibility indicator, where the experimental class achieved a score of 2.71 compared to 0.78 in the control class, with a difference of 1.93. This indicates that students who learned using the developed E-LKPD were more capable of generating various solution strategies in solving transformation geometry problems. Differences were also observed in originality (0.65), fluency (0.26), and elaboration (0.23). Overall, these findings indicate that the developed E-LKPD supports the improvement of various dimensions of students' mathematical creative thinking skills, particularly in enhancing flexible thinking.



(a) **(b)** **(c)** **(d)**

Figure 2. Examples of Students' Project Outcomes Based on Batik Putra Harapan Motifs

Figure 2 presents students' project outcomes in designing batik motifs based on Batik Putra Harapan by integrating the concepts of geometric transformations, namely translation, reflection, rotation, and dilation. Overall, the students' works demonstrate a variety of motifs combining floral elements, institutional symbols, and geometric patterns constructed through different transformation processes. In some designs, students used flower and root motifs as the main elements, which were then repeated, enlarged, or rearranged to represent the concepts of translation and dilation. In other designs, the use of school logos and textual elements was arranged symmetrically, reflecting the concept of reflection. Meanwhile, circular and radial patterns found in several works indicate the application of rotation in motif composition.

The diversity of these designs shows that students were able to integrate the concepts of geometric transformation into culturally based visual representations in a creative way. This is reflected in their ability to generate various ideas (fluency), apply different transformation strategies (flexibility), produce unique designs (originality), and develop ideas into complete visual products (elaboration). Thus, the project outcomes support the quantitative findings that E-LKPD based on ethnomathematics integrated with a deep learning approach is effective in fostering students' mathematical creative thinking skills in the topic of transformation geometry.

3.5 Dissemination Results

The dissemination stage was conducted on April 21, 2026, at Pondok Pesantren Putra Harapan Purwokerto. This activity involved 17 participants consisting of school management and mathematics teachers. At this stage, the researcher presented the development process, product features, validation results, practicality findings, and effectiveness results of the ethnomathematics-based E-LKPD integrated with a deep learning approach.

After the presentation, a discussion session was held, during which several technical questions emerged regarding the implementation of the E-LKPD, particularly concerning the distribution mechanism to students so that all students could access and edit the E-LKPD through the Canva platform without damaging or altering the designed layout. The participants also completed an evaluation questionnaire. The dissemination activity obtained a score of 97, indicating that the developed E-LKPD was considered highly feasible and appropriate as a mathematics learning resource. The participants highlighted the attractive design, communicative presentation, and the potential of the E-LKPD in supporting students' mathematical creative thinking skills. Overall, the dissemination results showed a positive acceptance of the developed E-LKPD and indicated its potential for wider implementation in mathematics learning.

4. DISCUSSION

4.1. Validity Discussion

The validation results indicate a significant improvement in the quality of the developed E-LKPD after the revision process. The increase in the average score from 2.03 in the first validation stage to 3.78 in the second stage suggests that the product has met the criteria of a highly valid learning resource. This improvement indicates that the revisions successfully addressed the weaknesses identified by the validators in the aspects of content, media, and language.

In terms of content, the integration of ethnomathematics and a deep learning approach plays an important role in strengthening the pedagogical validity of the product. The learning activities are not only focused on mastering transformation geometry concepts but also encourage students to explore these concepts through culturally relevant contexts close to their daily lives. The use of Batik Putra Harapan motifs enables abstract concepts such as translation, reflection, rotation, and dilation to be represented in a visual and contextual form. This helps students develop a more meaningful conceptual understanding compared to procedural-based learning. This finding is in line with Abbas et al. (2024), who emphasized that local cultural artifacts can serve as effective learning media in geometry instruction.

In terms of media, the improvement in validity indicates that the E-LKPD meets the criteria of a proper digital learning environment. Revisions in navigation, visual layout, accessibility, and interactive features have enhanced the usability of the product in the context of independent learning. A more systematic and interactive media design also contributes to increased student engagement during the learning process.

Meanwhile, language validity improved after revisions were made to instructions, activity descriptions, and usage guidelines. Clear and communicative language is essential in digital learning materials, as students are expected to learn independently. These improvements help reduce ambiguity, enabling students to understand tasks and learning activities more accurately.

Overall, the high validity scores indicate that the integration of ethnomathematics and a deep learning approach not only enhances content relevance but also strengthens the pedagogical appropriateness of the E-LKPD. In contrast to conventional worksheets that tend to emphasize procedural exercises, the developed E-LKPD encourages students to construct knowledge through cultural exploration, reflection, discussion, and project-based activities. Therefore, the developed E-LKPD can be considered a valid learning resource that supports meaningful mathematics learning in transformation geometry.

4.2. Discussion on Practicality

As for the results of this research indicate that this developed E-LKPD has a high level of practicality, marked by ease of use, attractive appearance, and its ability so that students can understand more easily the material on geometric transformations. This practicality is inseparable from the digital format of the E-LKPD, which allows students to learn more flexibly, interactively, and independently. Digital technology-based learning media has been proven effective to increase student engagement in mathematics learning through more attractive and interactive visual presentations compared to conventional media (Wang & Li, 2024). Furthermore, the integration of local cultural context through the use of Putra Harapan Batik motifs in presenting questions also increases students' learning motivation, as the learning material becomes more meaningful and closer to their daily experiences. This aligns with research findings that show that an ethnomathematics approach can enhance students' engagement as well as their conceptual understanding in mathematics learning (Sunzuma & Maharaj, 2021). Moreover, the use of technology-based teaching materials has also been proven effective in encouraging active student participation and contributing to the improvement of learning quality, including the development of creative thinking skills (Zhao et al., 2021; Ningsih et al., 2024).

4.3. Practicality Discussion of the E-LKPD

The research results indicate that the developed E-LKPD obtained an average practicality score of 3.38, which falls into the highly practical category. This finding suggests that students were able to use the E-LKPD easily and follow all learning activities presented in a systematic manner. The high level of practicality is not only influenced by the attractive digital interface but also by the learning design grounded in deep learning principles, namely meaningful, mindful, and joyful learning.

In terms of meaningful learning, students learned transformation geometry concepts through a culturally relevant context, namely Batik Putra Harapan. This context helped students connect mathematical concepts with real-life situations, thereby facilitating a more meaningful conceptual understanding.

In terms of mindful learning, students were not only required to solve problems but were also engaged in observation, discussion, reflection, and justification of their chosen strategies. These activities provided opportunities for deeper thinking during the learning process and supported active knowledge construction.

Meanwhile, joyful learning was realized through the use of interactive digital media, attractive visual design, and project-based activities involving the creation of batik motifs based on geometric transformations. These project activities allowed students to express their creative ideas through independently developed designs, thereby enhancing engagement and learning enjoyment.

Overall, the practicality of the E-LKPD does not merely reflect ease of use, but also its ability to support active, reflective, and creative learning. The developed features enable more flexible learning, while project-based activities provide opportunities for students to explore various problem-solving strategies.

These findings are in line with previous studies stating that digital learning materials and ethnomathematics-based approaches can enhance student engagement in mathematics learning. However, this study is distinctive in integrating ethnomathematics, a deep learning approach, and a digital E-LKPD into a single instructional product, thereby producing a more meaningful, reflective, and contextual learning experience that supports the development of students' mathematical creative thinking skills.

4.4. Discussion of Effectiveness and Mathematical Creative Thinking Ability

The Mann–Whitney U test results indicated a significant difference in students' mathematical creative thinking ability between the experimental and control classes. In addition, an effect size value of 0.337 suggests that the use of an ethnomathematics-based E-LKPD integrated with a deep learning approach had a moderate effect on improving students' mathematical creative thinking ability (Cohen, 1988.; Field, 2013).

In this study, mathematical creative thinking ability was analyzed through four indicators, namely fluency, flexibility, originality, and elaboration. These indicators represent essential dimensions of creativity, including the ability to generate multiple ideas, apply various strategies, produce unique ideas, and develop ideas in detail (Thornhill-Miller et al., 2023)

The improvement in **fluency** occurred because students were actively engaged in observing and exploring the Batik Putra Harapan motifs from the beginning of the learning process. They were encouraged to identify various types of transformations embedded in the batik patterns and to generate multiple possible answers when solving given problems. This activity enabled students to produce a greater number of ideas in mathematical problem-solving. Student reflections also showed that they were able to understand the connection between mathematics and culture through batik motifs representing geometric transformations such as translation, reflection, rotation, and dilation. This finding is consistent with Ningsih et al. (2024), who stated that ethnomathematics-based learning can enhance students' mathematical creative thinking skills.

The **flexibility** indicator showed the most prominent improvement compared to the other indicators. This can be explained by the characteristics of project-based learning, which encourages students to view problems from multiple perspectives. During the learning process, students engaged in discussions, explored designs using Canva, and considered various transformation possibilities in constructing batik patterns. These activities enabled students to develop diverse problem-solving strategies. In addition, positive learning experiences made students more comfortable in exploring alternative solutions. This finding is supported by Majidi et al. (2025), who stated that ethnomathematics-based Project-Based Learning can enhance students' mathematical creative thinking ability.

For the **originality** indicator, improvement occurred because students were not only required to apply transformation procedures but also to produce new batik designs through the given project. Although all students used the same types of transformations—translation, reflection, rotation, and dilation—each student produced a unique design. This demonstrates their ability to generate original ideas in applying geometric transformations. Student reflections further supported this finding, as they expressed that the project allowed them to express creativity through batik design while also recognizing the real application of mathematics in cultural contexts. According to Thornhill-Miller et al. (2023), originality refers to the ability to produce unique and novel ideas or products.

For the **elaboration** indicator, improvement was observed although it was not as strong as in the other indicators. Students began to explain transformation steps in more detail; however, their ability to develop and elaborate mathematical ideas still requires further practice. Student reflections indicated that they gradually became able to connect mathematical processes with their final designs, although some initially experienced difficulties in linking mathematical concepts with cultural contexts. This shows that elaboration skills develop gradually over time. This finding aligns with Susanti and Novtiar (2022), who stated that elaboration requires continuous practice to develop optimally.

The students' project outcomes provided qualitative evidence supporting the quantitative findings. All students produced diverse batik designs despite using the same cultural context and transformation concepts. This diversity indicates that students not only understood the mathematical concepts but were also able to apply them creatively in visual products. Furthermore, student reflections showed that ethnomathematics-based learning provided meaningful and enjoyable learning experiences and increased their interest in mathematics due to its connection with batik culture. Therefore, the improvement in mathematical creative thinking ability is reflected not only in posttest scores but also in the learning process, experiences, and student-produced artifacts.

4.5. The Role of Ethnomathematics and the Deep Learning Approach in the Construction of Mathematical Concepts

The findings of this study indicate that Batik Putra Harapan functions not only as a learning context but also as a medium for constructing mathematical concepts. Through the observation of batik motifs, students were able to directly identify the concepts of translation, reflection, rotation, and dilation, which had previously been learned in an abstract form. This finding is consistent with Abbas et al. (2024), who stated that local culture can serve as an effective medium in helping students understand geometric transformation concepts in a contextual manner.

This conceptual construction process is strengthened through the implementation of a deep learning approach integrated into each stage of learning. In the **meaningful learning** aspect, students connect geometric transformation concepts with familiar local cultural contexts. In the **mindful learning** aspect, students engage in discussion, exploration, investigation, and reflection to identify mathematical relationships embedded in batik motifs. Meanwhile, the **joyful learning** aspect is reflected through the use of Canva and project-based activities that create an enjoyable learning atmosphere. This finding is in line with Akmal et al. (2025), Hamidah et al. (2025), and Rahayu et al. (2025) who emphasize that the deep learning approach encourages students to construct conceptual understanding more deeply through active engagement in the learning process.

In addition, classroom observations during the implementation showed that the use of Batik Putra Harapan motifs as a learning context successfully attracted students' attention and helped them relate geometric transformation concepts to local cultural practices. However, in this study, the cultural context was still presented in a digital form through the E-LKPD. The use of authentic Batik Putra Harapan artifacts in classroom instruction has the potential to provide a more immersive learning experience, thereby further strengthening the connection between mathematical concepts and the cultural knowledge being studied.

4.6. Research Novelty and Implications

The novelty of this study lies in the integration of ethnomathematics, a deep learning approach, and the Project-Based Learning model within a digital E-LKPD to enhance students' mathematical creative thinking skills in the topic of geometric transformations. Previous studies have generally focused on developing ethnomathematics-based E-LKPD (Liesandra, S. O., & Nurafni, 2022; Ainiyah, N., & Loviana, 2024), applying ethnomathematics to improve creativity (Ningsih et al., 2024), or examining project-based learning with an ethnomathematics context (Febiyani & Ardiansyah, 2025). In contrast, this study integrates these three components simultaneously into a single instructional design supported by the local cultural context of Batik Putra Harapan.

In addition, this study does not only assess students' mathematical creative thinking skills through tests, but also through the project outcomes produced by the students. Thus, this research contributes to the development of mathematics learning that is more contextual, creative, and oriented toward students' learning experiences.

4.7. Limitations of the Study

This study has several limitations. First, the implementation was conducted in only one school with a relatively limited sample size; therefore, the generalization of the findings should be made with caution. Second, the learning implementation was carried out using a two-day block teaching schedule, which limited students' time for exploration and reflection. Third, the study focused only on the topic of geometric transformations. Therefore, future research is recommended to implement the E-LKPD in other mathematics topics with a longer implementation period and a larger number of participants.

5. CONCLUSION

This study developed an ethnomathematics-based Electronic Student Worksheet (E-LKPD) integrated with a deep learning approach on the topic of geometric transformations for Grade IX students. The development process produced a product categorized as highly valid, with a final validity score of 3.78, and highly practical, with a practicality score of 3.38. The effectiveness test results indicated a significant difference between students who used the developed E-LKPD and those who experienced conventional instruction (Mann–Whitney $U = 93.00$; $p = 0.046$), with a moderate effect size ($r = 0.337$). The findings show that the developed E-LKPD is effective in supporting students' mathematical creative thinking skills. Improvements were observed across all creativity indicators, namely fluency, flexibility, originality, and elaboration, with the most prominent improvement occurring in flexibility. This indicates that the implementation of a deep learning approach, which integrates meaningful, mindful, and joyful learning experiences through ethnomathematics-based activities, provides opportunities for students to explore various solution strategies and develop mathematical ideas more creatively. The novelty of this study lies in the integration of ethnomathematics and a deep learning approach in the development of a digital E-LKPD using Batik Putra Harapan motifs as a learning context for geometric transformations. Therefore, the developed E-LKPD can serve as an innovative learning resource that supports contextual, meaningful, and culturally based mathematics learning while enhancing students' mathematical creative thinking skills. This study has limitations related to the relatively small sample size and implementation in only one school. Future research is recommended to involve a larger and more diverse group of students, extend the implementation period, and examine the use of the E-LKPD in other mathematics topics.

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