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LKPD Based on Ethnomathematics Lompek Kodok Game to Facilitate Students' Mathematical Creative Thinking Skills

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ABSTRACT

This research aims to develop a valid and practical Student Worksheet (LKPD) based on ethnomathematics of the traditional game lompek kodok to facilitate the creative thinking skills of junior high school students on flat plane geometry materials. This research uses the development method (Research and Development) with a 4D model which includes the stages of Definite, Design, Develop. and disseminate. This research is sufficient at the Develop stage. The field trial was carried out at SMP Negeri 04 Bengkulu Tengah with 30 students in grade VII and 1 mathematics teacher. With validation sheet instruments, student response questionnaires, and teacher response questionnaires. The results of the study showed that the LKPD developed was valid with a total score of 77.14% from the assessment of material experts and 82.22% from the assessment of media experts. Then, LKPD was declared practical with a total score of 85.83% from the student response questionnaire and declared practical with a score of 85.41% from the mathematics teacher response questionnaire. In this study, it can be concluded that the LKPD developed is valid and practical so that it is suitable for use as a mathematics teaching material that integrates local culture while facilitating the creative thinking skills of students at the junior high school level.

1. Introduction

21st century mathematics education requires students to not only master mathematical concepts and procedures, but also to have high-level thinking skills, such as critical thinking, creativity, reasoning, and problem-solving[1]. This urgency is strengthened by the results *of the Programme for International Student* Assessment (PISA) 2022 which shows that the mathematical abilities of Indonesian students are still below the *national average of the Organisation for Economic Co-operation and Development* (OECD). [2] In line with that, the Achievement of Mathematics Learning in the Independent Curriculum emphasizes the importance of developing logical, analytical, systematic, critical, and creative thinking skills through mathematics learning[3]. Therefore, teaching materials are needed that are able to facilitate creative thinking skills through contextual and meaningful learning.

The ability to think mathematical creatively, according to Munandar (2009) in Maryati and Nurkayati (2021), includes four indicators, namely *fluency*, *flexibility*, *originality*, and elaboration, which allow students to produce various ideas and problem-solving [4]strategies. However, the creative

[1] Angio et al., "INTEGRATION OF 4C (CRITICAL THINKING, CREATIVITY, COMMUNICATION, COLLABORATION) SKILLS IN THE IMPACTFUL CURRICULUM FOR MATHEMATICS LEARNING"; Ika and Sukarna, "High-Level Thinking Ability in Solving HOTS Problems for Mathematics Subjects"; Rahmat Badawi, Harahap, and Nasution, "A SYSTEMATIC STUDY OF STUDENTS' MATHEMATICAL ABILITIES IN 21ST CENTURY LEARNING."
[2] OECD, "PISA 2022 Results (Volume III): Creative Minds, Creative Schools, PISA."
[3] Setiyan, A., "Guide to Advanced Phase A – F and Phase F Mathematics Subjects."
[4] Maryati and Nurkayati, "Analysis of Mathematical Creative Thinking Ability of Senior High School Students in Algebraic Materials"; Agustina, Masrukan, and Walid, "Analysis of Mathematical Creative Thinking Ability Reviewed from Self-Regulated Learning in the CPS Learning Model Assisted by Open-Ended Questions."

thinking skills of junior high school students are still relatively low, including in geometry material[5]. The findings [6] found that the mathematical creative thinking ability of junior high school students in space building materials was very low, while [7] similar findings were reported in grade VII flat building materials. Showing low creative thinking skills in geometry materials, especially in the indicators of *flexibility* and *originality*, due to learning that is still dominated by procedural questions and single answers[8]. This condition is influenced by teacher-centered learning so that students' opportunities to explore and discover ideas independently are limited [9]

The characteristics of cognitive development of junior high school students also support the need for contextual learning. According to Piaget, students aged 12–15 years are at the formal operational stage so that they begin to be able to think abstractly [10]. However, based on Van Hiele's theory, most students are still in the early stages of the deduction level so they still need concrete experience in understanding the concept of geometry [11]. Thus, learning that relates mathematical concepts to real experiences through meaningful activities is a relevant alternative to facilitate students' creative thinking skills.

One of the teaching materials that can support these needs is the Student Worksheet (LKPD), which functions as a learning guide as well as helping students analyze, conclude, and develop understanding of the material [12]. A good LKPD must meet the aspects of validity and practicality through expert assessment and user trials [13], supported by an attractive display to increase learning motivation [14]. Various studies have developed ethnomathematic-based LKPD on traditional games, such as congklak and marbles, with valid and practical results [15]. However, the research generally focuses on critical thinking or problem-solving skills. Research on new creative thinking skills has been carried out on the engklek game and has been proven to give positive results [16]

One of the traditional games that has the potential to be developed is *the lompek kodok, a* typical Bengkulu game that contains the concepts of geometry, chances, and summation[17]. Research by Ananda et al. (2024) identified various mathematical concepts in the game, while Putri et al. (2024) showed that the *lompek kodok* game can support mathematics learning, although it is still oriented towards critical thinking skills[18]. The findings show that the *lompek kodok* game has potential as a context for ethnomathematics-based mathematics learning. Based on previous studies, ethnomathematics-based LKPD research generally still uses the game of *congklak, marbles*, or *engklek* and is oriented towards critical thinking and problem-solving skills[19]. Meanwhile, research on the *lompek kodok game* is still limited to the exploration of mathematical elements [20]and their

[5] Sari and Afriansyah, "Students' Mathematical Creative Thinking Ability and Belief in Linear Equations and Inequality Materials."
[6] Andiyana, Maya, and Hidayat, "ANALYSIS OF MATHEMATICAL CREATIVE THINKING SKILLS OF JUNIOR HIGH SCHOOL STUDENTS ON BUILDING SPACE MATERIALS."
[7] Aulia et al., "THE INFLUENCE OF PBL MODELS ON STUDENTS' GEOMETRY KNOTS."
[8] Gestiani and Listyani, "DESCRIPTION OF MATHEMATICAL CREATIVE THINKING SKILLS OF JUNIOR HIGH SCHOOL STUDENTS"; Sularni and Asmara, "Analysis of Mathematical Creative Thinking Ability of Junior High School Students on Equations and Linear Equations of One Variable."
[9] Siregar et al., "Improving Students' Creative Thinking Skills Through Realistic Mathematical Approaches."
[10] Arliansyah Maulana, "Piaget's Theory of Cognitive Development at the Formal Operational Stage."
[11] Qur'ani et al., "Van Hiele Level on Concrete and Formal Operational Cognitive Development."
[12] Ramadhani and Aufa, "Development of Game-Based LKPD to Improve Critical Thinking of Grade III Elementary School Students."
[13] Samosir and Simatupang, "Analysis of Validity and Practicality of the Development of Problem-Based Student Worksheets (LKPD) in Statistical Materials."
[14] Hasanah et al., "Development of Image-Based Student Activity Sheets (LKPD) to Improve Generic Science Skills."
[15] Mania, Jamaluddin, and Kusumayanti, "Development of Ethnomathematics-Based LKPD to Improve Students' Critical Thinking Skills"; Wulandari and Yahfizham, "Development of Marble-Based Student Worksheets on Two-Variable Linear Equation System Material."
[16] Ardiansyah et al., "Innovation of Ethnomathematics Teaching Materials through Engklek Games with Game-Based Learning on Students' Creative Thinking Abilities"; Aulia et al., "THE INFLUENCE OF PBL MODELS ON STUDENTS' GEOMETRY KNOT-ASSISTED KNUCKLE"; Prasetya et al., "The Implementation of Ethnomathematics through Traditional Games on Geometry Materials on Students' Creative Thinking Skills."
[17] Ananda, Risnanosanti, and Syofiana, "Ethnomathematics on the Traditional Game of Bengkulu Frog Jump."
[18] Putri et al., "Implementation of Ethno-STEM Learning through the 'Lompek Kodok' Game to Enhance Critical Thinking Ability."
[19] Ardiansyah et al., "Innovation of Ethnomathematics Teaching Materials through Engklek Games with Game-Based Learning on Students' Creative Thinking Abilities"; Mania, Jamaluddin, and Kusumayanti, "Development of Ethnomathematics-Based LKPD to Improve Students' Critical Thinking Skills"; Prasetya et al., "The Implementation of Ethnomathematics through Traditional Engklek Games on Geometry Materials on Students' Creative Thinking Skills"; Wulandari and Yahfizham, "Development of Marble-Based Student Worksheets on Two-Variable Linear Equation System Material."
[20] Ananda, Risnanosanti, and Syofiana, "Ethnomathematics on the Traditional Game of Bengkulu Frog Jump."

application to critical thinking skills[21]. In fact, the characteristics of this game based on jump patterns and geometric shapes have the potential to facilitate creative thinking skills like *engklek games*. Therefore, this research offers novelty through the development of LKPD based on ethnomathematics of *the lompek kodok game* to facilitate the creative thinking skills of junior high school students on flat building materials. Based on this description, this study aims to develop a valid and practical ethnomathematics-based LKPD of *the lompek kodok* game to facilitate the creative thinking skills of junior high school students on flat building materials and describe its feasibility based on the results of expert validation and user responses.

2. Research Design and Methodology

This research is a *research and development* research using a 4D model proposed by Sivasailam Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel in Ade Rahayu (2025), which includes four stages, namely *Define* (definition), *Design* (design), *Develop* (development), and *Disseminate* ([22]dissemination. In this study, the development stage is sufficient by limiting the implementation to *the Development stage*. The restriction is based on research objectives that focus on product development as well as testing its feasibility through validity and practicality assessments.

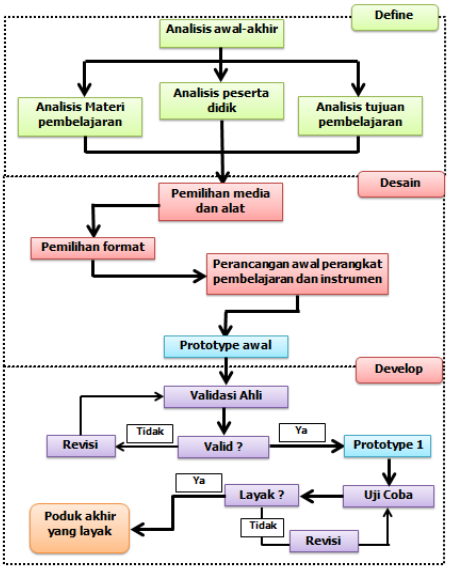


Figure 1. (Research Flow Chart)

The *define stage* is carried out to identify product development needs through early-end analysis, analysis of student characteristics, material analysis, task analysis and formulation of learning objectives. At this stage, a study was carried out on the characteristics of junior high school students, the mathematics materials to be developed, and the potential for the integration *of the lompek kodok* game as an ethnomathematical context in learning. The *design stage* aims to design the initial prototype of the LKPD. Activities at this stage include the preparation of research instruments, the selection of media and presentation formats, as well as the design of initial products. The LKPD is designed to contain learning activities that accommodate indicators of mathematical creative thinking ability, namely *fluency, flexibility, originality,* and *elaboration.*

The *develop stage* is carried out through expert validation and limited trials. Product validation involves two validators consisting of material experts and media experts. The subject matter expert assesses the suitability of the content, the correctness of the concept, and the relationship of the LKPD with the indicator of creative thinking ability. Media experts assessed the feasibility aspects of the graphics, display, layout, and presentation of the LKPD. Input and suggestions from validators are used as the basis for product revision until a valid LKPD is obtained

[21] Putri et al., "Implementation of Ethno-STEM Learning through the 'Lompek Kodok' Game to Enhance Critical Thinking Ability."
[22] Ade Rahayu, "Research and Development Methods (R&; d) : Definition, types and stages"; Wiranata and Sujana, "Development of Student Worksheets Based on Contextual Problem Solving for Social Problem Materials for Class IV Elementary School."

for trial. The research instrument consists of a material expert validation sheet and a media expert validation sheet. All instruments use a five-level Likert scale with a score range of 1 to 5. The research data in the form of validation score results were analyzed in a quantitative descriptive manner. The percentage of validity is calculated using the formula of Arikunto (2013) in Lestari et al., as follows:

$$\text{Nilai} = \frac{\text{Skor perolehan}}{\text{Skor maksimal}} \times 100\ \% \qquad \text{....Source :}^{23}$$

The results of the calculation are then converted into the category of assessment of the interpretation criteria of the percentage of validity referring to Arikunto (2010) in Radhifah & Lufri (2024) LKPD products are declared valid to be used if valid Based on these criteria, In this study the product is declared to meet the validity criteria if it obtains a percentage of ≥ 61%. Meanwhile, the percentage is in the range of <61%. indicates that the product has not met the validity criteria.

The Practicality Test was carried out on 30 students of SMPN 04 Bengkulu Tengah and one mathematics teacher. This activity aims to obtain data on product practicality through filling out student and teacher response questionnaires. The aspects assessed include ease of use, attractiveness of appearance, and LKPD material in supporting the learning process. Analysis of practicality sheets from student and teacher respondent instruments using a four-level likert scale with a score range of 1 to 4. The results of the calculation were then converted into the category of assessment of the interpretation criteria of the percentage of practicality referring to Arikunto (2010) in Radhifah & Lufri (2024). Based on these criteria, the product is declared to meet the practicality criteria if it obtains a percentage of ≥ 61%, which is in the practical or very practical category. The percentage < 61% indicates that the product does not meet the criteria of practicality.

3. Findings and Discussion

3.1. Findings

The *Define* stage is carried out to identify the initial conditions of learning and the development needs of LKPD through early-end analysis, student characteristics, task analysis, and curriculum and material analysis. The early-end analysis shows the need for mathematics teaching materials that are not only oriented towards mastering concepts and procedures, but also provide opportunities for learners to explore and develop mathematical ideas. Therefore, learning needs to be supported by activities that are contextual, interesting, and provide space for students to find various possible solutions.

The analysis of student characteristics shows that learning activities need to be adjusted to the characteristics of junior high school students who need a concrete, contextual, and close learning experience to their environment. In mathematics learning, activities such as determining several possible solutions to a problem, using different strategies, generating ideas that are not fixated on examples, and explaining and developing the results of thinking can provide space for the development of creative thinking skills. This condition shows the need for LKPD that not only presents exercises with a single solution procedure, but also contains open problems that allow the emergence of various mathematical ideas.

Furthermore, task analysis is carried out to determine the activities that students need to do in achieving learning goals. The task is arranged in stages, starting from identifying mathematical elements in the given context, determining and applying the concept of flat building, exploring various alternative solutions, to generating and explaining an idea or design. Each activity is directed to provide opportunities for students to generate various ideas, use various strategies, put forward different ideas, and develop ideas systematically. The results of the task analysis are the basis for determining the activities and instructions contained in the LKPD.

The analysis of the curriculum and materials was carried out with reference to the Mathematics Learning Outcomes Phase D in the Independent Curriculum. Based on this analysis, geometric materials, especially flat buildings, were chosen because they are related to the concepts

[23] Lestari, Alberida, and Rahmi, "Validity and Practicality of Student Worksheets (LKPD) of Kingdom Plantae Materials Based on a Scientific Approach for Class X Students of High School/MA."

of shape, size, circumference, and area that can be explored through contextual problems. This material also has a strong connection with the traditional game *of lompek kodok* because the game arena is composed of tiles that can be studied based on their shape and size. This interconnectedness allows students to identify geometric elements in a cultural context close to their environment, then explore various possible sizes, shapes, or tile arrangements through open-ended problems. These activities provide space for students to generate various ideas, use various strategies, produce different designs, and develop and explain their ideas. Based on the results of the analysis, the flat building material with the context of *the Lompek kodok game* was chosen as the basis for the development of LKPD to facilitate mathematical creative thinking skills.

To provide an overview of the ethnomathematical context used in the development of LKPD, the *game of lompek kodok* has a game arena with certain shapes and arrangements that can be associated with the concept of flat building. The shape of the game arena is then used as a context in learning activities to help students identify mathematical concepts and explore various ideas and problem-solving strategies, shown in figure 2.

Figure 2. (Game Arena *lompek kodok*)

The *Design stage* is carried out by compiling an initial design of the LKPD based on the results of needs analysis, analysis at the *Define stage*. The LKPD is designed to pay attention to the characteristics of students, learning outcomes, materials, and indicators of mathematical creative thinking ability. The product developed consists of a cover page, instructions for use, introduction to the *Lompek kodok game*, learning activities, activities that facilitate the four indicators of creative thinking ability, and reflection. The overall view of the LKPD products that have been developed can be seen in Figure 3.

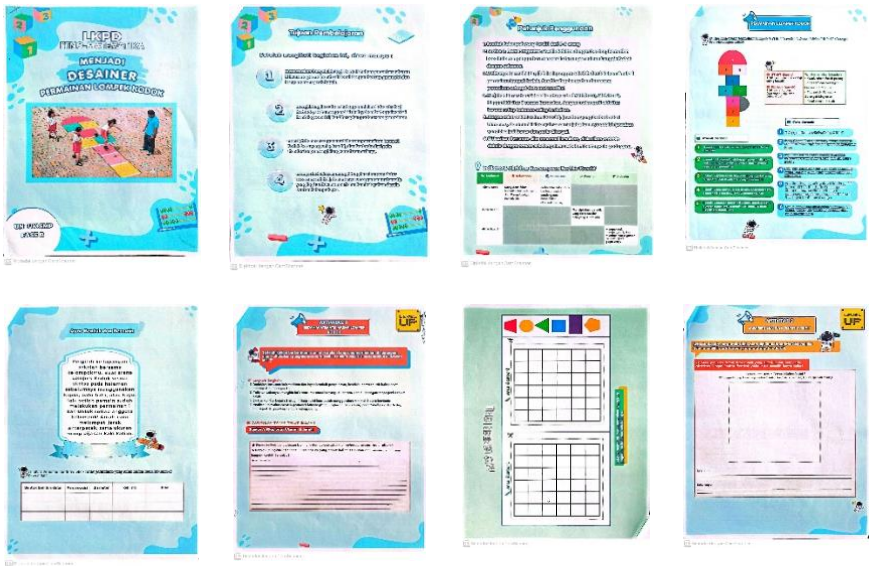


Figure 3. Early LKPD Design

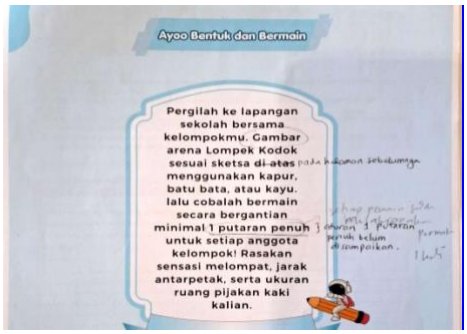
The overall view of the LKPD that has been developed can be seen in Figure 3. Each section in the LKPD is designed in stages by integrating the context of the *Lompek kodok game* into the learning of flat building material. The activities contained in the LKPD are then arranged according to the indicators of creative thinking ability that are to be facilitated. The relationship between learning activities and indicators of creative thinking ability is presented in Table 1.

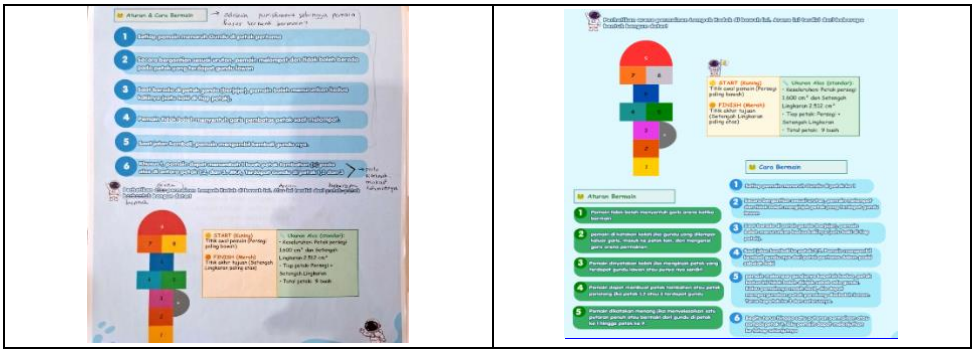
Table 1. Indicators of Creative Thinking Ability in LKPD activities

Yes	Indicators of Creative Thinking Ability	Activities	Details
1	*Fluency*	Activity 1 (Part A)	Giving students space to identify mathematical information from the results of the play and find interesting ideas
2	*Flexibility*	Activity 1 (Part B)	Searching for various possible answers to a mathematical problem and alternative solutions
3	*Originality*	Activity 2	gives learners the space to design their own arena and be different from the original arena
4	*Elaboration*	Activity 3	Explain the part of the arena design that has been created and detail it and can give his opinion

The next stage is the development stage (*Develop*). At this stage, the LKPD is based on the ethnomathematics of *the lompek kodok* game which has been designed at the *Design stage through a* review *process* by material expert validators and media expert validators. *The review* was conducted to identify shortcomings and provide input on the suitability of the material content, presentation, language, display, and media aspects in the LKPD. Based on the results of the *review*, revisions were made to the LKPD in accordance with the suggestions given by each validator. Some of the main revisions made to the LKPD are presented in Table 2, while other revisions were made to several parts of the product according to the validator's input.

Table 2. LKPD Product Revision

Before	After
	
	



After all improvements are made based on validator input, the LKPD is reassessed to obtain product validity results. The results of the assessment from the validators, material experts and media experts were then analyzed to determine the level of validity of the LKPD. A recapitulation of the validation results of the two validators is presented in the next table.

Table. 3 Results of the Material Expert Validation Test

Yes	Validated aspects	Quantity	Maximum Score	Validity Value	Criteria
1	Content eligibility	40	50	80 %	Valid
2	Presentation	21	30	70 %	valid
3	Language	20	25	80%	valid
	Total Quantity			230 %	
	Average			77,14%	valid

Based on Table 3, the results of the assessment by material experts show that the LKPD developed obtained a percentage of 77.14% that has met valid criteria. The assessment is based on several aspects, namely the feasibility of content, presentation, and language. In addition to being validated by material experts, the LKPD developed was also validated by media experts. This validation aims to assess the feasibility of the product in terms of appearance, presentation, and ease of use. The results of the validation of media experts are presented in Table 4.

Table 4. Media Expert Validation Test Results

No	Aspects validated	Quantity	Maximum Score	Validity Value	Criteria
1	Content eligibility	28	30	93 %	valid
2	Display	28	35	80 %	valid
3	Application	18	25	72%	valid
	Total Quantity			245,33 %	
	Average			82,22%	Very valid

Based on Table 4, the results of the assessment by media experts obtained a percentage of 82.22% with a very valid category. These results show that the developed ethnomathematics-based LKPD has met the eligibility criteria from the media aspect, including graphic display, display, and application. The next stage is a practicality test in the field trial. This field trial stage involved 30 students of SMP Negeri 04 Central Bengkulu. This field trial was carried out for three meetings, the first meeting was that students played live games on the field activity 1, namely identifying and taking out many ideas from the *lompek kodok game arena*, as well as looking at problems from various perspectives and finding alternative solutions. The second meeting is to make a lompek kodok game design by creating a unique and different idea from the existing arena design, and the third meeting is to detail 1 design that has been made in activity 2. After students complete all the activities contained in the LKPD, students will fill out a questionnaire about how practical the LKPD they have used. The following Table 5 is the result of the students' practicality questionnaire:

Table 5, the results of the students' practicality questionnaire

Aspects assessed	Total score	Maximum score amount	Presentase	Category
Design	410	480	85,41%	Very practical
Material	405	480	84,37%	Very practical
Language	421	480	87,71%	Very practical
Overall average			85,83%	Very practical

Based on Table 5, the results of the practicality test by students obtained a percentage of 85.83% with the category of very practical. These results show that the developed LKPD is easy to use and can support the mathematics learning process. To strengthen these results, practicality assessments are also carried out by teachers as learning practitioners. The results of the practicality assessment questionnaire by teachers are presented in Table 6.

Table 6.Results of the teacher practicality questionnaire

Aspects assessed	Total score	Maximum score amount	Presentase	Category
Content eligibility	10	12	83,33%	Very practical
Material	10	12	83,33%	Very practical
Language	11	12	91,67%	Very practical
Graphics	10	12	83,33%	Very practical
Overall average			85,41%	Very practical

Based on Table 6, the results of the practicality assessment by teachers obtained a percentage of 85.41% with the category of very practical. These results show that the ethnomathematics-based LKPD of *the lompek kodok game* is considered easy to use in the learning process, both in terms of material presentation, ease of use, language, and learning implementation. The percentage obtained indicates that the LKPD has met the practicality criteria so that it is suitable for use as one of the teaching materials in mathematics learning in grade VII of junior high school. In addition to being reviewed from the practical aspect, the implementation of LKPD also produced various student responses that reflected indicators of mathematical creative thinking ability. An example of the results of students' work on each indicator is presented in Figure 4.

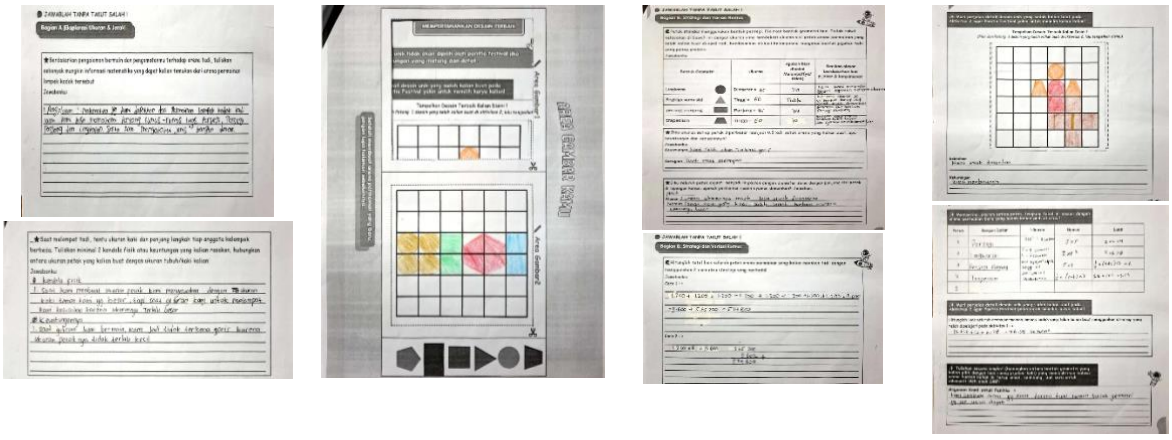


Figure 4. Examples of LKPD Work

Based on Figure 4, students show different characteristics of creative thinking skills in each indicator. In the *fluency* indicator, students are able to generate several solution ideas. In the *flexibility* indicator, students use more than one completion strategy. In the *originality* indicator, students produce arena designs that are varied and different from the examples given, while in the

elaboration indicator, students are able to explain and detail the designs that are made systematically. These findings show that activities in LKPD provide opportunities for students to display every indicator of mathematical creative thinking ability. The results of validation, practicality, and examples of students' work results show that the ethnomathematics-based LKPD of the *Lompek kodok game* has the potential as a feasible teaching material to facilitate mathematical creative thinking skills.

3.2. Discussion

The development of LKPD based on the ethnomathematics of the *lompek kodok game* through the *Define*, *Design*, and *Develop stages* produces products that meet valid and very practical criteria. These results show that the integration of traditional games as a learning context is able to produce teaching materials that are in accordance with the characteristics of junior high school students. In addition, the preparation of activities based on *fluency*, *flexibility*, *originality*, and *elaboration* indicators provides opportunities for students to develop mathematical creative thinking skills through contextual problem solving.

The validation results showed that LKPD obtained a valid category based on the assessment of material experts and very valid based on the assessment of media experts. The findings indicate that the feasibility aspects of content, presentation, language, display, and application have met the principles of teaching material development. The revisions made based on validator input also improve the quality of the product before being tested on students. These results are in line with the research of Samosir and Simatupang (2022) and Mania et al. (2021) which stated that ethnomathematics-based LKPD developed through an expert validation process generally meets the criteria for suitability for use in learning.

The practicality test showed that LKPD obtained a very practical category based on the responses of students and teachers. The high level of practicality shows that LKPD is easy to use, has an attractive appearance, and supports the implementation of mathematics learning. These findings are strengthened by examples of students' work results that show the emergence of *fluency*, *flexibility*, *originality*, and *elaboration* indicators during completing activities in the LKPD. These results are in line with the research of Ardiansyah et al. (2023) and Wulandari and Yahfizham (2025) who reported that traditional game-based LKPD is able to increase student involvement in learning through contextual and meaningful activities.

Overall, the results of the study show that the ethnomathematics-based LKPD of the *Lompek kodok game* is suitable for use as an alternative to mathematics teaching materials on flat building materials to facilitate the creative thinking skills of junior high school students. This research provides novelty through the use of the traditional game of *Lompek Kodok* as a context for the development of LKPD which is oriented towards the ability to think creatively mathematically. However, this study is still limited to testing validity and practicality up to the *develop* stage, so the effectiveness of LKPD in improving creative thinking skills cannot be concluded.

4. Conclusion

Based on the results of the research and development that has been carried out, the LKPD based on the ethnomathematics of the Lompek kodok game on flat building materials has been successfully developed through a 4D model which is limited to the develop stage. The validation results showed that LKPD met the eligibility criteria, with a validity percentage of 77.14% of material experts with valid categories and 82.22% of media experts with very valid categories. The results of the practicality test also showed that the LKPD obtained a percentage of 85.83% based on student responses and 85.41% based on teacher responses, both of which are included in the very practical category.

Activities in the LKPD are designed by integrating indicators of mathematical creative thinking ability, namely *fluency, flexibility, originality,* and *elaboration*. The results of the students' work show that the activities developed provide opportunities for students to generate various ideas, use alternative strategies, make different arena designs, and develop and explain the ideas produced. Thus, the ethnomathematics-based LKPD of the lompek kodok game was declared valid and very

practical and suitable to be used as an alternative to mathematics teaching materials on flat building materials to facilitate the mathematical creative thinking skills of junior high school students.

This research is still sufficient in the development and testing of the validity and practicality of the product up to the develop stage. Therefore, further research can continue to the Disseminate stage to test the effectiveness of LKPD on students' mathematical creative thinking skills.

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Statement on the Use of Generative Artificial Intelligence(AI)

During the preparation of this manuscript, the authors used generative artificial intelligence (AI) tools solely to support the scientific writing process. Specifically, Grammarly was used to improve grammar, language quality, readability, and writing clarity. The AI tools were not used to generate research ideas, analyze data, interpret findings, or draw scientific conclusions. All study design, data collection, analysis, interpretation of results, and conclusions were conducted and verified entirely by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the content presented in this manuscript.

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