



Polygon Area Board Game for Building Thinking Skills in Area Conservation and Measurement

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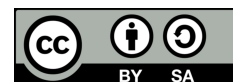
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ABSTRACT

This study aimed to develop a board game to enhance fifth-grade students' understanding of area concepts and the law of conservation of area in polygons. The research employed the ADDIE model, covering analysis, design, development, implementation, and evaluation stages. Expert validation and classroom trials were conducted to assess validity, practicality, and effectiveness. The results showed that the board game achieved a validity score of 89% (very feasible) and improved students' test performance by 23%. Students exhibited high engagement and active participation during learning activities. The study highlights the importance of integrating design elements such as layout, color, and illustration to support conceptual understanding. It concludes that well-designed board games can effectively foster critical thinking and motivation in elementary mathematics learning.

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1. INTRODUCTION

Mathematics is often perceived as a difficult and intimidating subject by elementary students. This perception arises because the learning process is frequently rigid and formal, lacking variety and engaging approaches that align with students' developmental characteristics. Consequently, many students dislike mathematics, resulting in low learning outcomes. These challenges highlight the need for alternative strategies to make mathematics learning more enjoyable and meaningful.

Learning is a complex process that requires the integration of methods, materials, and media to achieve optimal results [1]. Effective media selection must consider students' developmental stages and teachers' ability to operate the media to enhance understanding and support learning success [2]. The use of learning media should also align with learning objectives, classroom contexts, and students' characteristics to ensure meaningful learning experiences [3]. In addition, teachers need to adapt instructional media creatively to make abstract or difficult material more concrete and engaging for students [4]. Instructional media play a crucial role in supporting learning by helping students understand abstract concepts, attracting attention, reducing verbalism, and creating engaging learning experiences [5]. However, many existing mathematics learning media remain limited in facilitating manipulative activities and character development, which are essential for students to grasp concepts, principles, and problem-solving processes. This situation highlights the need for more innovative, interactive, and character-oriented mathematics learning media that can actively engage students in the learning process.

Game-based media has emerged as a promising solution to these challenges. By integrating game elements, learning becomes more enjoyable, motivating students to actively participate and reducing boredom. Studies have revealed that integrating educational games into instruction not only improves learning outcomes but also supports active participation and collaboration among students [6]. In addition, the interactive nature of games encourages collaboration, critical thinking, and problem-solving, which are essential components of 21st-century learning. Among various types, board games offer a simple and effective medium for delivering mathematical content while fostering active engagement. Therefore, this study focuses on developing a board game designed to enhance students' understanding of polygon area concepts and the law of conservation of area, aiming to provide both effective learning outcomes and enjoyable classroom experiences.

Recent studies also highlight that game-based learning significantly improves not only cognitive outcomes but also affective domains such as motivation and engagement, [7], [8], [9]. Furthermore, [10] emphasize that non-digital board games can be as effective as digital tools in enhancing students' conceptual understanding, particularly when learners are given autonomy during gameplay. [9] Further underline that playful pedagogy through board games contributes to the development of students' executive functions and higher-order thinking skills. In addition, [11] as well as [12] propose practical frameworks and best practices for designing educational board games, ensuring that the integration of gameplay elements aligns with learning objectives.

Therefore, this study focuses on developing a board game designed to enhance students' understanding of polygon area concepts and the law of conservation of area, aiming to provide both effective learning outcomes and enjoyable classroom experiences. This research is expected not only to contribute to the effectiveness of mathematics learning but also to enrich the literature on educational board game design tailored to elementary students and 21st-century learning principles.

A board game is a type of game in which tools or parts of the game are placed, moved, or moved on a surface that has been marked or divided according to a set of rules [8]. Another similar view states that a board game is a set of games with tools and parts that are placed, moved, moved and placed on a surface that has been marked or divided according to a set of rules that have been established [13]. In other words, a Board Game can be stated, it is a game that is carried out on a flat plane with a set of rules that have been set and must be passed by the player to complete the mission on the theme that has been created. When used in a lesson, the mission and theme created will be adjusted to the theme that will be studied by the students. Board Games are chosen as the main media of educational games because they have several advantages that do not exist in other types of games, such as rules in games that make students learn to obey existing rules, or learn discipline, trigger social interaction between players, train students on how to live social life, and so on [4], [14], [13]. Board games can also grow new abilities in a fun and fun way. Regarding the Board Game of polygons which consists of pieces of polygons shapes is very possible to be used as a medium to build a broad understanding of the law of area conservation [15], [16], [12] course, armed with experience manipulating the Board Game of polygons can be formed the ability to think about the law of area conservation.

As well as learning media, mathematics learning also requires appropriate teaching materials to support student understanding. However, existing teaching materials and media are still limited in addressing students' needs for hands-on, game-based approaches that link mathematical concepts to enjoyable activities. In particular, there is a lack of board game-based media specifically designed to develop understanding of polygon areas and the law of conservation of area. This gap highlights the need for innovative learning resources that not only explain formulas but also engage students through interactive and motivating experiences. Therefore, this study seeks to develop a polygon area board game as an alternative instructional medium that addresses this gap while fostering both conceptual understanding and active learning.

This is because teaching materials are one of the important components and can be conveyed by the media in learning [17]. The materials or subject matter used by teachers or students must first be systematically arranged in accordance with their competencies, objectives, and implementation [3]. Teaching materials are materials that are designed and compiled systematically, used to assist teachers in carrying out teaching and learning activities [13]. Teaching materials can be used in the learning process, both in print and non-print form. This is implied from the point of view of the form of teaching materials that can be packaged in the form of media. Because the media functions as a conveyor (sender). At the same time, it provides convenience and motivation in the process of teaching and learning activities carried out by teachers and students. Moreover, if the learning material is delivered contextually, students can carry out their learning tasks optimally. In this context, Board Games are in the form of pieces in the form of areas of polygons that were developed to realize the media about the area of polygons.

The board game about the areas of polygons area should serve as a: (a) guidelines for teachers who will direct all their activities in the learning process and at the same time are the substance of competencies that should be taught/trained to students, (b) guidelines for students that will direct all their activities in the learning process and at the same time are the substance of the competencies that they should learn/master, (c) Assisting teachers in teaching and learning activities, (d) Assisting students in the learning process, (e) as a learning tool to achieve lesson objectives, (f) to create a conducive learning environment/atmosphere [18]. Therefore, in realizing Board Games for mathematics learning facilities about the areas of polygons, as an effort to provide learning facilities that meet the standards of the mathematical process, and the competencies that students must have, it is necessary to study and plan carefully. Board Games should provide a fun learning experience but be able to master the material correctly. In this case, it is necessary to design and develop Board Game media about the area that can deliver teaching materials correctly. In addition, Board Game media must have quality that is able to attract student motivation as well as be solutive, innovative, and creative.

Moreover, if learning material is delivered contextually, students can perform their learning tasks more effectively. Although board games have been widely used in other educational contexts, there is limited research on their application in teaching mathematical concepts such as area conservation in polygons, particularly for elementary students. Existing instructional approaches often emphasize memorization of formulas rather than providing opportunities for hands-on exploration and manipulation, which makes it difficult for students to fully grasp the principles of area measurement. This gap highlights the need for innovative media that not only supports conceptual understanding but also motivates students through engaging and interactive activities. To address this challenge, the present study developed a board game using polygon-shaped pieces to facilitate students' understanding of area concepts and the law of conservation of area. Specifically, the study aims to design, validate, and evaluate the effectiveness of the developed board game in supporting fifth-grade students' conceptual learning.

2. RESEARCH METHOD

The method for the development of Board Game media about the areas of polygons uses the stages of analyze, design, develop, implement, evaluate from the five stages of ADDIE [1]. The ADDIE model guided the research process, beginning with an analysis of existing instructional media on polygon areas, followed by the design of a board game aligned with curriculum objectives to facilitate student learning and provide experiences related to the law of conservation of area. ADDIE was selected because it offers a systematic and flexible framework for developing instructional media, allowing researchers to move through the stages of analysis, design, development, implementation, and evaluation in a structured manner. Compared to other models, ADDIE is particularly well-suited for this study as it emphasizes iterative refinement based on feedback, which ensures that the developed board game is not only theoretically grounded but also practical, engaging, and responsive to students' learning needs. The development of the Board Game media on the areas of polygons was based on analysis, theoretical foundations, and relevant learning materials. The implementation stage involved 30 Grade V elementary school students selected through purposive sampling. Data were collected using a conceptual understanding test, an observation sheet assessing engagement and participation, and a student response questionnaire. Each instrument was validated by experts, and reliability was tested using Cronbach's alpha. Although the sample size was limited and no control group was included, the findings provide valuable preliminary insights into the board game's practicality and potential effectiveness in supporting conceptual learning. This sampling method was chosen because Grade V students had already been introduced to the concept of polygon areas in the curriculum, making them an appropriate target group for testing the media. Providing these details helps clarify the scope of participants and the extent to which the findings can be generalized. The evaluation of media development uses information from the instrument in the form of a board game media questionnaire about the areas of polygons and the results

of measuring the students' ability to master the material of the areas of polygons through a test. Here is Figure 1, ADDIE Model Stages.

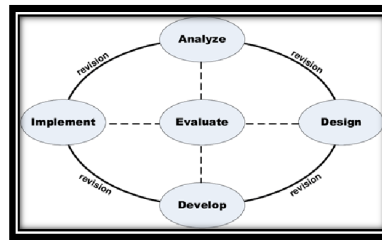


Figure 1. ADDIE Model Stages [1]

In this case, the first stage is to analyze 10 math board games compiled and published through the You-Tube platform. Analysis of the availability and suitability of board game types with mathematics materials for elementary school students, using 10 components, namely: meticulousness of content, determination of scope, digestibility of teaching materials, use of language, face and packaging, illustrations, completeness of components, attractiveness of interest, consistency of teaching materials, and suitability with writing guidelines [19], [20]. From several board games that have met the content/material requirements, followed by analyzing the components of typography, color, layout, and illustration [21]. The criteria for assessing the results of the analysis, design, and development of board game-assisted teaching materials refer to [10]. While the evaluation primarily relied on observations of students' engagement and performance, which may involve subjective judgment, additional structured methods such as video analysis or peer assessments could enhance the objectivity and reliability of the data collection process.

Table 1. Assessment Criteria for Board Game Media of Areas of Polygons

No.	Criterion	Result Interval
1.	High	66,67% - 100%
2.	Midle	33,34% - 66,66%
3.	Low	< 33,33%

The second stage is to design a board game based on data from analysis and theory about the character of grade V elementary school students. This is used as a consideration that the media is designed to be used by grade V elementary school students in learning the areas of polygons and the law of conservation of area. The third stage is to prepare teaching materials according to the curriculum that is structured and systematic. It is then packaged into board game media. The fourth stage, the media board game about the areas of polygons is ready for use by students. The fourth stage produced a board game on the areas of polygons that was ready for student use. The fifth stage measured its effectiveness and efficiency through formative evaluation. However, this study did not include a control group for comparison (e.g., students taught with traditional methods), which limits the extent to which improvements can be attributed solely to the board game intervention.

3. RESULT AND ANALYSIS

Results

Thematically and based on the results of analysis on 10 board games about elementary mathematics on the YouTube platform which were then implicated into board game design, a description of board games about elementary mathematics was found as follows. Table 2 below presents the results of media analysis on elementary school mathematics board games.

Table 2. Results of Media Analysis of Elementary Mathematics Board Game Media

Component	Indicator	Result	Criterion
Tipografi	1. Easy-to-read writing	80%	High
	2. Typeface increases students' interest in learning.	73,33%	High
	3. Font size is adjusted to the characteristics of the student	80%	High
Color	1. Colors are adjusted to the characteristics of the student	80%	High
	2. The colors used are in accordance with the content of the material presented.	80%	High
Layout	1. Layout suitability	66,66%	Midle
	2. Effective and efficient	80%	High
	3. The visuals presented in the layout are easy for students to understand.	76,66%	High
	4. Layouts can increase students interest and attention.	83,33%	High
Illustration	1. The image used clarifies the material or information conveyed.	76,66%	High
	2. The images used are engaging, motivating and help student retention and understanding.	70%	High
	3. The images used are appropriate and meaningful	73,33%	High

First, all indicators of the typography component show high criteria both on; (1) the writing is easy to read, (2) the font style increases the students' interest in learning, and (3) the font size is adjusted to the characteristics of the students. Second, all indicators of color components, namely (1) colors according to the characteristics of students, (2) colors used according to the content of the material presented, show the same results, which is 80%. This shows that the color component in the 10 boardgames analyzed has high criteria. Third, the layout component shows medium and high criteria. Of the four indicators, namely (1) Layout Suitability, (2) effective and efficient, (3) the visuals presented in the layout are easy for students to understand, and (4) the layout can increase students' interest and attention. There are indicators that need to be developed, namely (1) layout suitability which shows a result of 66.66%. This indicates a moderate criterion. Next, in indicator (3) the visuals presented in the layout are easy for students to understand, even though they show high criteria, they still show a result of 76.66%. Indicator (2) is effective and efficient showing a result of 80% or high criteria. The last indicator (4) layout can increase students' interest and attention, showing a result of 83.33% or a high criterion. Fourth, the illustration component shows high criteria. However, the three indicators analyzed were (1) the images used clarified the information material conveyed, (2) the images used were interesting, motivating, and supported student retention and understanding, and (3) the images used were appropriate and meaningful, showing percentages of 76.66%, 70%, and 73.33%. While these results indicate positive short-term outcomes, the study did not include long-term data on how well students retained the knowledge or how the game influenced their future learning, which would be essential for evaluating the sustained effectiveness of the board game.

The results of the experience using board game media that have been developed show that the learning experience of finding formulas and determining the size of the areas of polygons area takes place in a fun, active and interactive manner. Learning activities about the areas of polygons using board game media also show the initial experience of students transforming areas of polygons into other areas of polygons, so as to meet the law of conservation of area. Figure 2 below illustrates student learning outcomes using board games in the subject of flat shapes (area of polygons).

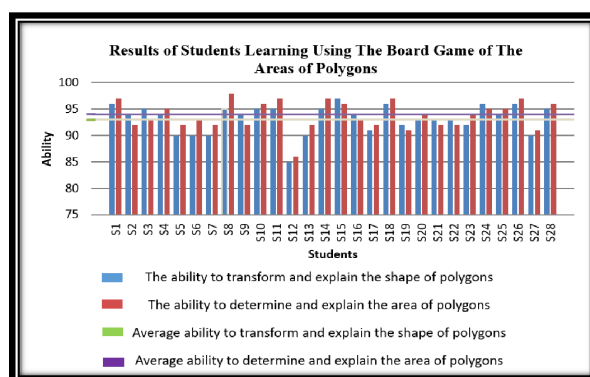


Figure 2. Diagram of Student Learning Results Using Board Game Areas of Polygons

Based on the results of observation, students were able to explain the changes in the curves of the polygon region that occurred due to the transformation carried out. It is the experience of finding the area conservation of the polygonal region. Armed with the experience of polygonal region transformation through the developed polygonal region board game, students' extensive area conservation thinking skills emerged very well (average = 93). Furthermore, to measure the ability to determine the formula and size of the areas of the polygons, students were given five (5) questions about polygonal region, like triangle, parallelograms, trapezoids, kites, and rhombuses. The results obtained showed that the ability to determine the formula and measure of the area of the polygons area was very good (average = 94). However, since the research team itself developed the board game, there may be an inherent bias in interpreting these results. Independent validation from third-party educators or researchers would be valuable to strengthen the credibility and objectivity of the findings.

Discussion

Responding to the results and analysis, the research needs to a polygons region board game media, especially on the letter style indicator, because it is necessary to choose the typeface that students prefer more, so that students' interest in learning increases. The results of the color analysis obtained, and the finding that the polygon region board game needs to be made using colors that suit the characteristics of the students, namely bright and cheerful colors. Looking at the results of the analysis of the layout components, there is still room for improvement. First, in the suitability of the layout, it is necessary to handle the creation of a board game area with the areas of polygons, so that the message is easily conveyed in complete. Then related to the visuals presented in the layout, it must be easy for students to understand, so it is necessary to mark elements on the polygon region board game on the sides and corners so that it can lead students to transform the polygon region board game into other forms of areas of polygons. This is in line with the opinion of [22] who stated that learning media designed with appealing visual

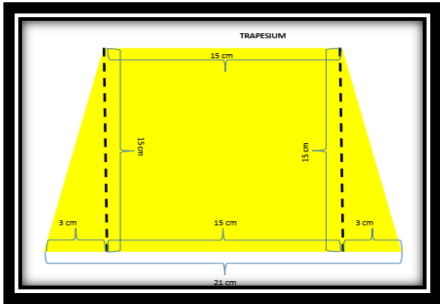
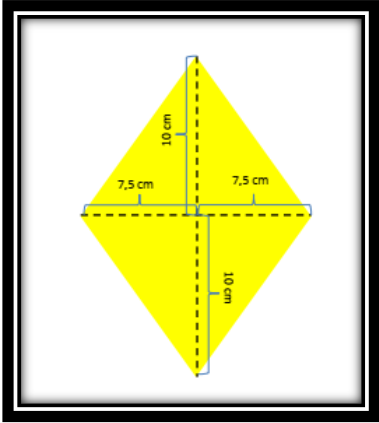
elements and appropriate typographic and color choices can significantly increase students' engagement and motivation in learning. Furthermore, [23] also emphasized that well-structured visual layouts help learners process information more effectively through visual clarity and organization

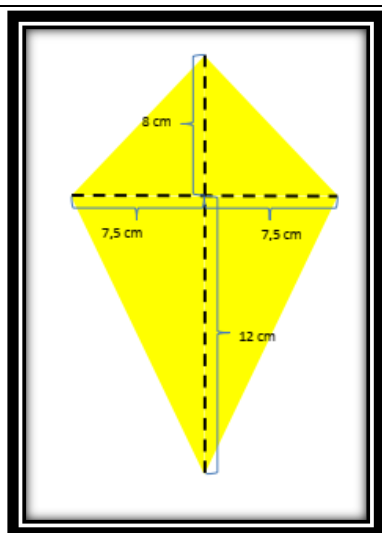
Reflecting on the results of the analysis of the illustration components, the areas of polygons board game will be made by considering the quality of the image (in this case represented by the proportional size of the polygons region board game) in order to clarify the material presented. In addition to the size that is suitable for students to use so that it is more comfortable and attractive, it can motivate and help student retention and understanding. In addition, the materials used are chosen so that they are comfortable and safe to use and can show suitability and meaning for students. This is in line with the opinion of [24] who explained that clear and proportionally designed visual representations help learners process information more effectively through dual-channel learning (verbal and visual). Similarly, [25] stated that learning media with well-designed visuals and user-friendly materials can improve students' motivation and engagement in the learning process.

Therefore, in making the design of teaching media for the area of polygons in the form of board games, it is necessary to pay attention to the indicators of the analysis results of the board game that have been found. Based on these findings, the development of board games in the areas of polygons is focused on indicators (1) the suitability of the layout, (2) the images used are interesting, motivating and help student retention and understanding, (3) the font style increases students' interest in learning, (4) the images used are appropriate and meaningful, (5) the visuals presented in the layout are easy for students to understand, and (6) the images used clarify the material or information conveyed, without ruling out indicators that already have a result of 80% (high criteria). This is in line with the opinion of [25] who emphasized that learning media design should integrate both visual and verbal elements effectively to improve comprehension and retention. Moreover, [26] stated that learning environments incorporating interactive and visually appealing elements can significantly enhance student motivation and engagement. Similarly, [27] also explained that the effectiveness of instructional media depends on its ability to attract attention, convey messages clearly, and match learners' characteristics.

From the results of the analysis obtained, several indicators still need to be developed, especially in the illustration and layout components. In addition, it is also in the components that still show moderate criteria, and the results are below 80%. Following up on that, a storyboard was made to produce a wide board game of areas of polygons that were representative of elementary school students. The description and description of the design of the board game areas of polygons are presented in Table 3 below.

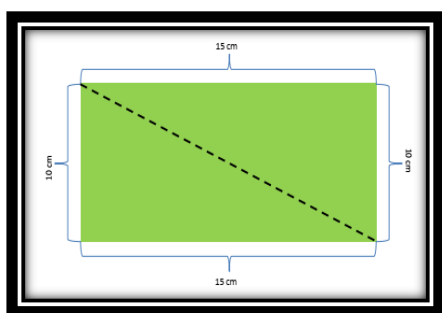
Table 3. Storyboard Broad Game Media of the Areas of Polygons

Picture	Information
	<i>Broad game</i> to find the formula of the area of the trapezoidal area. Side size required: above $a = 15$ cm, bottom $b = 21$ cm dan high $t = 15$ cm. One of the triangles regions formed by the height line of the trapezoid is cut to move its storage to the sloping side of the trapezoid. Obtained Rectangular shape, so that $\begin{aligned}\text{Trapezoid area} &= \frac{1}{2} \times (a + b) \times t \\ &= \frac{1}{2} \times (15 + 21) \text{ cm} \times 15 \text{ cm} \\ &= 270 \text{ cm}^2\end{aligned}$
	<i>Board game</i> to find the formula for the area of rhombus with a diagonal size of one (d_1) = 20 cm and diagonal two (d_2) = 15 cm. The two diagonals cut off one of the diagonals and cut it again into two congruent parts. The two parts can be attached to other sides of the rhombus until they find a rectangular shape. The rectangle size is d_1 and $\frac{1}{2} d_2$, so that $\begin{aligned}\text{rhombus area} &= \frac{1}{2} \times d_1 \times d_2 \\ &= \frac{1}{2} \times 20 \text{ cm} \times 15 \text{ cm} \\ &= 150 \text{ cm}^2\end{aligned}$



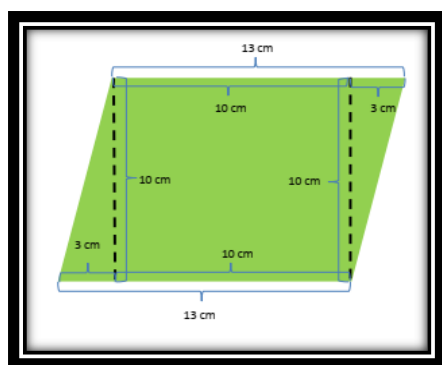
Broad game to determine the formula of the area of the kite with a diagonal size of one (d_1) = 20 cm and diagonal two (d_2) = 15 cm. It is shown by cutting d_1 and cutting it again at the advanced mark of d_2 so that two triangles are obtained. Next, move the pieces of the two triangles to the oblique side of the remaining kite so that a rectangular shape is obtained with the size d_1 and $\frac{1}{2} d_2$. Thus

$$\begin{aligned}\text{Kite area} &= \frac{1}{2} \times d_1 \times d_2 \\ &= \frac{1}{2} \times 20 \text{ cm} \times 15 \text{ cm} \\ &= 150 \text{ cm}^2\end{aligned}$$



Broad game to determine the formula for the area of a triangle. Indicated by a rectangle with a base (a) of 15 cm and a height (t) of 10 cm. It is then divided in half using a diagonal line, to show the presence of two congruent triangles. Found

$$\begin{aligned}\text{Triangle area} &= \frac{a \times t}{2} \\ &= \frac{15 \text{ cm} \times 10 \text{ cm}}{2} \\ &= 75 \text{ cm}^2\end{aligned}$$



The broad game to determine the formula of the area area of parallelogram with the size of the base = 13 cm and height = 10 cm is shown by making a height line, then cut off one of the triangle areas that formed and glued it to the other side of the parallelogram, thus forming a rectangle. It is found that the line of parallelogram height is equal to the width of the rectangle, then

$$\begin{aligned}\text{parallelogram area} &= a \times t \\ &= 13 \text{ cm} \times 10 \text{ cm} \\ &= 130 \text{ cm}^2\end{aligned}$$

The materials chosen to realize the areas of polygons board games are red, yellow, green acrylic. Colors that are easy for students to recognize and love. The designed size is comfortable enough to hold. A material that is safe to manipulate because it is smooth and not sharp, and not easily damaged. This board game consists of several pieces of polygons, are: triangles, and squares in various sizes like the ones in the picture on the storyboard. All of the pieces of areas of polygons are packaged in a storage box made of transparent plastic material so that it has attractiveness, so as to cause the curiosity of grade V elementary school students when they are going to learn about the areas of polygons. The following is a picture of the Board Game based on the storyboard and storage box that will be used to store the Board Game.

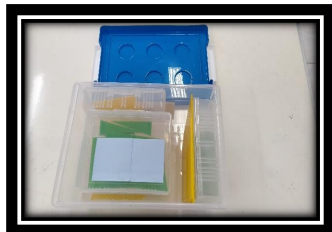


Figure 3. Board Game Media is Packaged Using a Storage Box

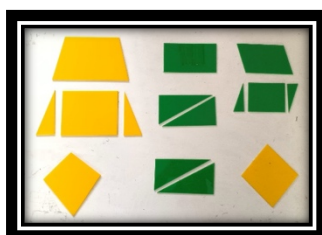


Figure 4. Each Piece of Areas of Polygons Packed in Storage Box

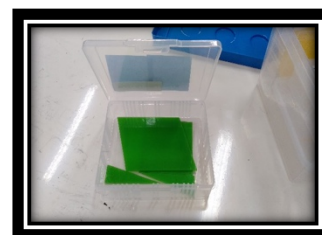


Figure 5. Board Game Media Areas of Polygons

The implementation of the polygon board game media which begins with two pieces of right triangle that can transform to a rectangular and vice versa, becomes an introduction to learning and understanding the law of conservation of area. In addition, students' ability to transform any polygons (board games) to other forms of polygons, is one of the steps that leads to the discovery of the formula for the area of a sector polygons through the area of a rectangular area.

Armed with this transforming experience, we further learned the transformation of the trapezoidal board game, parallelogram, rhombus and others into a rectangular flat building shape. So that students can find and understand the formula of the area of each polygons and can find the size of the area of the polygons through the calculation and application of the formula that has been found.

4. CONCLUSION

In designing and developing mathematics learning media about the area of polygons in the form of board games, this study demonstrates that the game can effectively support grade V elementary school students and teachers by making learning more fun, active, and interactive. The results indicate that design components such as layout, typography, color, and illustrations were generally rated highly, and these features contributed to improving student engagement and conceptual understanding. For example, clear illustrations and side/corner markings helped students visualize the conservation of area and derive formulas for polygon areas more easily. However, while the findings confirm short-term improvements in students' ability to understand and apply the concept of area conservation, the study does not provide follow-up data to assess the long-term impact of the board game on sustained learning outcomes. Future research should therefore include longitudinal studies or independent validation to examine how these design features influence deeper and lasting mathematical understanding.

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