Vol. 15, No. 04, pp. 2314-2331, 2025 DOI: 10.23960/jpp.v15i4.pp2314-2331

Jurnal Pendidikan Progresif

e-ISSN: 2550-1313 | p-ISSN: 2087-9849

http://jpp.fkip.unila.ac.id/index.php/jpp/

Enhancing Early Mathematics Learning Through an Interactive Storybook: A Development and Validation Study

Yeni Solfiah[1,*], Mohd Nazri[2], Devi Risma[1], Defni Satria[1], Nanda Pratiwi[1], Eva Eriani[1], & Mastuinda[1]

[1]Department of Early Childhood Education, University of Riau, Indonesia

[2]Department of Educational Psychology and Counselling, University of Malaya, Malaysia

*Corresponding email: yeni.solfiah@lecturer.unri.ac.id

Received: 18 August 2025 *Accepted: 16 September 2025* *Published: 07 November 2025*

Abstract: Enhancing Early Mathematics Learning Through an Interactive Storybook: A Development and Validation Study. **Objective:** This research aims to develop and implement an active mathematics learning paradigm for early childhood through illustrated storybooks that integrate fundamental mathematical concepts, namely numbers, patterns, geometry, measurement, and statistics. The goal is to provide a developmentally appropriate platform that encourages engagement, improves math proficiency, hones problem-solving skills, and makes learning more meaningful and enjoyable. **Methods:** The methodology used is a development research based on the Dick and Carey model. The validation process involved mathematicians, early childhood education experts, kindergarten educators, and media experts. Data were obtained through surveys, interviews, observations, and limited trials involving 14 children aged 5–6 years in Pekanbaru, Riau Province, Indonesia. Quantitative data analysis employed descriptive statistics, pretest-posttest comparisons, normality tests, and homogeneity tests. At the same time, qualitative data were obtained from expert evaluations and instructor comments. **Findings:** The validation results showed that the developed media met the criteria of validity, practicality, and efficacy, with scores from PAUD experts of 88.00%, mathematics experts of 89.33%, early childhood teachers of 81.54%, and media experts of 88.00%, with an overall category of "very good". In the limited trial stage, an average pretest score of 17.59 and a posttest score of 25.2 were obtained, indicating a significant increase in all mathematics indicators. The normality test ($p > 0.05$) indicated that the data were normally distributed, while the homogeneity test ($p > 0.05$) indicated that the data were homogeneous. The t-test results showed that the calculated t-value for all indicators was greater than the t-table value (1.771) with a significance level of $0.000 < 0.05$, indicating that the media had a significant impact on improving children's mathematics abilities. Observations revealed positive responses from the children, including increased interest, focus, and active involvement. **Conclusions:** Active math storybooks have been recognized as an innovative learning tool for early childhood, helping educators create a stimulating learning environment and serving as an effective resource for parents. The design, which combines stories, games, and interactive activities, has been proven to strengthen children's math skills.

Keywords: active learning design, early childhood, education, mathematics.

To cite this article:

Solfiah, Y., Nazri, M., Risma, D., Satria, D., Pratiwi, N., Eriani, E., & Mastuinda. (2025). Enhancing Early Mathematics Learning Through an Interactive Storybook: A Development and Validation Study. *Jurnal Pendidikan Progresif*, *15*(4), 2314-2331. doi: 10.23960/jpp.v15i4.pp2314-2331.

INTRODUCTION

Mathematics is one of the most fundamental domains of cognitive development in early childhood, serving as the foundation for higher-order thinking and problem-solving skills that children will continually encounter across various stages of education (Fayrus & Slamet, 2022; Solfiah, 2022). One of the key abilities acquired

by children through mathematics learning is the ability to think at a high level. This ability is highly significant because it encompasses multiple components that form the basis of children's knowledge and skills for the future (Solfiah, 2022). Consequently, mathematics education in early childhood is not merely an introduction to numbers and shapes, but an essential medium for stimulating cognitive growth, fostering logical reasoning, and building essential life skills.

The significance of early childhood mathematics education is unequivocal. Recognizing that children arrive at school with pertinent and engaging mathematical notions derived from their everyday experiences with mathematical elements or processes, education enriches programs with games, problems, play activities, and constructions related to a diverse array of mathematical concepts (Tzekaki, 2020). In kindergarten, children may encounter mathematical concepts during both unstructured play and structured activities. For instance, when children collaborate in small groups to resolve a mathematics issue, they must coordinate and organize their actions to efficiently find a solution. Mathematical structures arise from the coordination of actions in the activity (Breive, 2020).

The students he instructed inherently employed mathematics to analyze problems and apply them to everyday situations. For instance, a cohort of youngsters was enumerating individuals on the school bus on a certain day (e.g., currently, 11 are present and seven are absent; presently, 13 are present and five are absent; currently...). Facilitating children's natural connections between mathematics and real life can be a powerful approach to establishing a solid foundation in mathematics. The arithmetic competency of preschool children can indicate various future academic achievements, including reading skills, literacy, and later mathematical instruction. Given the importance of mathematics education for young children, it is imperative to integrate appropriate mathematical training into kindergarten (Chang, Chang, & Chang, 2024).

Mathematics is an essential part of human existence; inadequate mathematical skills in childhood have been demonstrated to produce long-term detrimental effects on subsequent schooling, career, and even mental health in maturity (Parviainen, Eklund, Koivula, Liinamaa, & Rutanen, 2023). Mathematics is present in daily life, and children use it to solve various simple problems. It is helpful to encounter while playing and engaging in children's routine activities. In the kindergarten stage, mathematics is introduced to students through active activities that are not only fun but also structured, utilizing various learning resources, educational play materials, songs, poems, and illustrated storybooks (Charlesworth, 2016).

Despite its importance, mathematics is often perceived as a difficult and less engaging subject by both children and adults. Many children struggle with abstract concepts, while parents and teachers may carry negative experiences from their own schooling that influence their attitudes toward teaching mathematics (Raharjo, Rasiman, & Untari, 2021). These challenges create environments that lack sufficient opportunities for children to engage in meaningful play and learning mathematics. The 2022 PISA report further highlights this issue, showing that Indonesian students' mathematics skills remain below several neighboring Southeast Asian countries (OECD, 2024). This underscores the urgency to reassess and redesign mathematics learning for children at various educational levels, especially at the foundational stage of early childhood education.

To address these challenges, recent studies have emphasized the role of scaffolded, play-based curricula that integrate manipulatives, developmentally appropriate visual aids, and problem-solving activities. Such approaches enhance autonomous numerical reasoning, pattern generalization, and spatial cognition (Torres-Peña, Peña-González, & Ariza-Echeverri, 2025).

Play-oriented, child-centered experiences have been proven to foster not only numeracy but also logical reasoning, which are vital competencies for long-term academic success (Veraksa, Sheridan, & Colliver, 2023). Moreover, embedding project-based activities allows children to act as primary agents of learning while maintaining a dialectical balance between child-centered exploration and teacher-directed guidance, extending Vygotskian scaffolding in authentic contexts (Veraksa et al., 2023). Moreover, the professional world requires human resources with high capabilities in implementing mathematics (Montague, Cotton, Hansen, & Price, 2018)

In addition to scaffolding, the integration of culturally responsive and contextually relevant learning materials has been shown to enhance children's problem-solving proficiency, confidence, and collaboration. When mathematics is presented in ways that connect to children's everyday lives, it fosters cultural relevance, equity, and engagement (Hunter & Miller, 2022). Research also indicates that physical activity and motor development are positively correlated with children's overall cognitive performance, encompassing mathematics, language skills, attention, and creativity (Stalchenko, Vanhala, Korhonen, & Aunio, 2023). Physical activities can support children's health and also contribute to their success in mathematics (Macdonald, Milne, Pope, & Orr, 2022). These findings indicate that mathematics learning should be active, embodied, and situated within meaningful experiences to maximize both cognitive and socio-emotional growth.

Previous studies have explored innovative learning media, such as the *lift-the-flap book*, which has been shown to effectively improve children's understanding of number recognition and addition concepts (Nugrahani & Permata, 2021; Zummiasa, Armia, Mas'udah, Widayati, & Reza, 2023). However, the current research takes it a step further by designing an illustrated storybook as a medium for active learning in mathematics. The storybook integrates core mathematical concepts—including numbers, patterns, geometry, measurement, and statistics—into engaging narratives with colorful illustrations and interactive tasks. Unlike previous media, this product offers a comprehensive framework to support mathematics learning while also stimulating imagination, creativity, and enjoyment.

Therefore, the objective of this study is to design an active mathematics learning medium for children aged 5–6 years through the use of an illustrated storybook. This product is validated by mathematicians and early childhood education specialists before being trialed in classroom settings. The illustrated storybook is intended to benefit not only teachers but also parents, enabling them to support children's mathematics learning in playful yet structured ways that are developmentally appropriate. In this way, mathematics education in early childhood can be repositioned as a joyful, meaningful, and effective process that lays a strong foundation for children's future learning trajectories.

METHOD

Participation

The participants in this study consisted of experts and practitioners in early childhood education, as well as kindergarten children in Pekanbaru, Riau Province, Indonesia. The experts involved were a lecturer from the Mathematics Education Study Program and a professor from the Early Childhood Education Study Program, Faculty of Teacher Training and Education, University of Riau. The kindergarten teachers involved in the product validation were active teachers at Tri Insani Permata Kindergarten and Laboratory Kindergarten of FKIP University of Riau. The main sample of this study consisted of children aged 5–6 years from Tri Insani Permata Kindergarten, who were selected through a random sampling technique. The

selection process involved randomly selecting one kindergarten in Pekanbaru City and then selecting two classes as research subjects.

Research Design and Procedures

This study employed a research and development method, utilizing a development model adapted from Dick and Carey (Fayrus & Slamet, 2022). This model is chosen because of its flexibility, which can be used in various forms of learning products (Koderi, Kuswanto, & Nuryati, 2021). The research procedure was carried out through the following stages: (1) analysis of learning needs and objectives; (2) designing an active mathematics learning design; (3) product development in the form of a picture storybook containing standard early childhood mathematics content (numbers, patterns, geometry, measurement, and statistics); (4) expert validation including content experts, learning design experts, and media experts; (5) product revision based on expert input; (6) limited trials on individuals and small groups; and (7) product evaluation through pre-tests and post-tests.

This study was conducted over six months. Furthermore, the steps involved in developing an active mathematics learning design are described as follows. Preliminary Research: This stage involved conducting a literature review and an initial survey to identify existing problems, needs, and theoretical foundations that support the product development process. The researcher collected preliminary data regarding field conditions, children's characteristics, and teachers' needs for the intended learning materials. Preparation and Needs Analysis: At this stage, a needs analysis was conducted for teachers. Additionally, a development plan was created, outlining the objectives, content, media, and methods to be implemented in the product.

Instrumentation: The researcher prepared several research instruments, including pretests and posttests, observation sheets, and validation questionnaires. These instruments were used to measure the product's effectiveness and to gather feedback from experts and users. Development (Initial Product Development): This phase focused on developing an initial prototype, such as an illustrated storybook. The product was created based on the results of the needs analysis and the design plan established in the previous stage.

Validation and Revision: The initial product underwent expert validation, involving specialists in early childhood education, media design, and content development. The validation results were used to refine and improve the product before it was tested with users. Small Group Trial and Revision: The revised product was tested with a small group of children and teachers to evaluate its practicality and user responses. Based on the findings from this trial, further revisions were made to ensure the product met users' needs more effectively.

Field Trial/Implementation: After being declared feasible, the product was implemented on a larger scale to assess its effectiveness and usability in real-world classroom settings. Dissemination and Documentation: The outcomes of the research and development process were disseminated through reports, journal articles, and an illustrated storybook product that integrates five key mathematical concepts. The goal was to enable teachers and early childhood education institutions to adopt and utilize the product widely.

Instruments

The research instruments included an observation sheet for early childhood mathematics ability, an expert validation questionnaire, and pre- and post-tests. The children's mathematics ability observation sheet was modified from instruments developed by Hornburg et al. (2021) and Outhwaite, Aunio, Leung, & Van Herwegen (2024), adjusting to the context of 5–6-year-old children in Indonesia. The observed aspects included the five components of the early childhood mathematics

content standards: numbers, patterns, geometry, measurement, and statistics. The instrument's content validity was tested through assessments by mathematics education experts, early childhood education experts, and kindergarten teachers. At the same time, its reliability was obtained through inter-rater reliability testing during a limited trial.

In this study, the mathematical abilities of kindergarten children were assessed using an observation sheet as the main evaluation instrument. The use of an observation sheet was chosen based on the characteristics of early childhood learners, who tend to learn through play and direct interaction with their environment. Therefore, their abilities are more accurately measured through observation of their behaviors and responses during learning activities. The observation sheet used in this study was the Early Childhood Mathematics Ability Observation Sheet, which was systematically designed to authentically assess children's mathematical abilities through daily activities and learning experiences using illustrated storybook media.

The use of an observation sheet was considered more reasonable and relevant than a written test for assessing young children's mathematical abilities. This is because written tests require symbolic and abstract thinking skills that are not yet fully developed in kindergarten-aged children. In contrast, observation sheets allow teachers or researchers to assess children's abilities naturally through their real behaviors within enjoyable play and learning contexts.

Table 1. Blueprint of the instrument used

Indicator	Sub-indicator	The Number of Items
Number	1. Naming numbers in sequence (1–10 or more). 2. Recognizing written numbers (numeral identification) 3. Name examples of number symbols and find them in their surroundings. 4. Skillfully use number symbols while playing. 5. Connect number symbols with number concepts. 6. Solve problems related to numbers, such as sharing candy with friends and counting the number.	6
Patterns	1. Creating or continuing simple patterns (color, shape, size) 2. Grouping objects based on certain criteria (e.g., color, shape) 3. Recognizes ABCD patterns, ABCD 4. Name examples of patterns in the environment, such as traffic lights, rainbows, and calendars. 5. Completes patterns visually, for example, an apple, an orange, a melon, a rambutan. 6. Applies skillfully to clap in patterns such as claps 1, 2, and 3.	6
Geometry	1. Recognizing basic shapes: circle, square, triangle 2. Grouping objects based on shape or size 3. Recognize the position of objects in their environment, such as above, below, right, left, inside, outside, and so on. 4. Create pictures consisting of geometric shapes, such as houses, buildings, and bridges.	5

	5. Children can combine two geometric shapes and combine them into one. For example, two triangles combined make a quadrilateral.	
Measurement	1. Recognizes comparisons between two objects, for example, longer, shorter, more, less, hotter, colder, and so on. 2. Understands non-standard measuring instruments such as thermometers, scales, and tape measures. 3. Able to see the comparison between two objects. 4. Skilled in using non-standard measuring instruments such as spans, footsteps, and so on. 5. Skilled in using standard measuring instruments, for example, measuring a friend's height with a tape measure, taking body temperature with a thermometer, and measuring weight with a scale.	5
Statistics	1. Grouping objects according to categories (color, shape, size) 2. Counting and verbally stating the total results of the grouping 3. Comparing graphs 4. Collecting data from the surrounding environment 5. Skilled at constructing graphs and skilled at comparing graph heights 6. Able to communicate graphs to classmates.	6

(modified from Hornburg et al., 2021; Outhwaite et al., 2024)

Data Analysis

The research data consisted of qualitative and quantitative data. Qualitative data were collected through interviews, responses, and suggestions from experts and teachers via open-ended questionnaires and observations during limited trials. Quantitative data were obtained from questionnaire scores and children's pre-test and post-test results. Quantitative data were analyzed descriptively by converting questionnaire scores into percentages and a Likert scale to illustrate the product's feasibility. Meanwhile, the effectiveness of the active mathematics learning design was analyzed by comparing children's pre-test and post-test results, thus obtaining an overview of the improvement in children's mathematics abilities after using the developed product.

To test the effectiveness of the active mathematics learning design, children's pre-test and post-test results were compared using a paired samples t-test. This test revealed significant differences between pre- and post-treatment scores, indicating improvements in children's math skills after using the developed product.

■ RESULT AND DISCUSSION

The implementation of this research utilizes the Dick and Carey development model, which emphasizes the systematic and structured process of developing instruction (Fayrus & Slamet, 2022). Each stage in this model is interconnected, resulting in a learning design that is theoretically valid and practically and effectively implemented in the field. In this research, the product developed is an Active Mathematics picture storybook for early childhood. This book contains standard early childhood mathematics content, including numbers, patterns, geometry, measurement, and statistics. Using an active mathematics approach, this book is designed to engage children directly in contextual and enjoyable play-based learning activities. The following research results and

discussions will be presented, based on the stages of the Dick and Carey model, beginning with the identification of learning objectives and concluding with summative evaluation.

Identify Learning Objectives

The primary goal of this development is to produce an active mathematics learning tool in the form of an illustrated storybook that includes the standard content for early childhood mathematics (numbers, patterns, geometry, measurement, and statistics). This book is designed to engage children in active, play-based learning, enhancing their understanding of mathematical concepts.

Initial observations at Tri Insani Permata Kindergarten in Pekanbaru suggest that conventional methods continue to dominate mathematics instruction in early childhood education (PAUD). Teachers use simple lectures, question-and-answer sessions, and practice exercises that involve copying numbers from worksheets. Learning media are also limited to whiteboards, textbooks, and worksheets, thus limiting children's opportunities to learn through contextual play activities. This situation impacts children's engagement in the learning process. Most children appear passive, simply following teacher instructions without engaging in much independent exploration. Mathematical play activities are also minimal, usually limited to simple counting of objects or copying number symbols. These conditions make children easily bored, unenthusiastic, and distracted during learning activities.

These findings reinforce the initial analysis that mathematics learning in early childhood education remains conventional and inadequate in stimulating active child engagement. Therefore, innovative media, such as stories, games, and exploratory activities, are necessary to help teachers deliver more engaging, meaningful, and personalized mathematics learning experiences to young children.

Instructional Analysis

In this instructional analysis stage, researchers focused on the basic mathematical skills, attitudes, and knowledge that children must develop to achieve learning objectives. Active math storybooks were developed to help children understand basic concepts and apply them through engaging and contextual play activities. The identification results showed that the mathematical skills that need to be developed include five main aspects. First, the number aspect, namely the child's ability to recognize, name, and count the number of simple objects around them. Second, the pattern aspect emphasizes the child's ability to recognize, arrange, and continue patterns from shapes or objects they encounter. Third, the geometry aspect, where children learn to recognize basic shapes and relate them to real objects in everyday life. Fourth, the measurement aspect, which trains children to compare sizes, lengths, or heights in simple ways. Fifth, the statistics aspect directs children to group objects, count their number, and present data in simple forms such as bar charts or pictures.

This analysis provides a crucial foundation for developing the content of an active, mathematics-based picture storybook. Based on children's needs in these five areas, the product is designed to encourage active involvement in the learning process while providing meaningful experiences that lay the foundation for early mathematics skills.

Analysis of Student Characteristics

At this stage, researchers analyzed child characteristics to develop an active, mathematics-based picture storybook designed to improve early childhood mathematical thinking skills. This analysis was based on observations at Tri Insani Permata Kindergarten, the research location.

Several important findings were obtained based on initial observations of children aged 5 to 6 years. First, some children have begun

recognizing the numbers 1–10 and naming them correctly, but still have difficulty connecting numbers with the exact number of objects. Second, children show enthusiasm when learning is linked to games or concrete activities, such as counting toys or stacking blocks, so contextual media is essential to facilitate their learning interests. Third, cooperative attitudes have begun to develop, as evidenced by the children's ability to work effectively in small groups. However, some individuals still prefer to win alone when participating in activities that involve counting or playing number-based games. Fourth, children appear more focused and motivated when teachers use interesting visual media, such as colorful pictures, animal characters, or stories related to everyday life.

Observations also show that children's math abilities vary. Some children can already recognize simple patterns and compare the sizes of objects, while others require more intensive guidance. These findings suggest the need for innovative, engaging, and developmentally appropriate learning media to stimulate their basic math skills.

This analysis of student characteristics is an important basis for designing storybook content. The material developed should align with the developmental needs of early childhood, particularly in cognitive aspects and logical thinking skills.

Performance Objective Analysis

This study's performance objectives aim to develop basic mathematical skills in children aged 5–6 years through the use of active, mathematics-based picture storybooks. These objectives cover five main content areas: numbers, patterns, geometry, measurement, and statistics, as follows:

a. Number content: (1) Children are expected to be able to say numbers in sequence (1-10 or more), (2) recognize written numbers, and (3) find examples of number symbols in the surrounding environment. (4) Children are also skilled at using number symbols in games, can connect number symbols with the concept of quantity, and can solve simple problems related to numbers, for example, sharing objects with friends.
b. Pattern Content: (1) Children can create or continue simple patterns based on color, shape, or size. In addition, (2) children can group objects based on certain criteria, (3) recognize repeating patterns (such as the ABCD pattern), and (4) name examples of patterns in the surrounding environment, for example, traffic lights or calendars. (5) Children can also visually complete patterns with concrete objects and imitate sound patterns through rhythmic clapping.
c. Geometry Content: (1) Children are expected to recognize basic shapes (circle, square, triangle), (2) group objects based on shape or size, and understand the position of objects in space (top-bottom, right-left, inside-outside). (3) Children can also make simple pictures using geometric shapes, for example, a house or bridge, and (4) combine two geometric shapes into a new shape, such as arranging two triangles into a square.
d. Measurement Content: (1) Children can recognize comparisons between objects (longer–shorter, more–less, hotter–colder), and (2) understand the use of non-standard measuring tools such as spans, footsteps, or tape. (3) Children also begin to recognize standard measuring tools, for example, measuring tapes, scales, or thermometers. They are skilled at using them in simple activities, such as measuring the height or weight of objects.
e. Statistics Content: (1) Children are expected to be able to group objects based on certain categories, (2) calculate and state the total results of the grouping, and (3) compare simple data through graphs. (4) Children can also

collect data from the surrounding environment, make simple graphs, compare the graphs' height, and communicate their observations to friends.

Developing Assessment Instruments

This research instrument consisted of three main types. First, an expert validation instrument involving early childhood education (PAUD) experts, mathematics experts, and teachers will be used to assess the theoretical and practical suitability of the product. Second, a questionnaire was used to gather responses from children and teachers regarding the level of interest, engagement, and usefulness of the media in learning. Third, a pretest and posttest were used to measure improvements in children's learning outcomes. The data obtained were analyzed using normality tests, homogeneity tests, and paired samples t-tests to test the significance f differences in ability before and after learning.

Developing Learning Strategies

The learning strategy is designed around contextual stories combined with active math activities. Children are introduced to number concepts through counting everyday objects, patterns by arranging repeating objects, geometry by observing shapes around them, measurement by comparing size or height, and statistics by grouping and presenting simple data. This approach makes learning more enjoyable, meaningful, and closer to children's real-life experiences.

Developing and Selecting Teaching Materials

The initial product is an active math picture storybook covering five main topics (numbers, patterns, geometry, measurement, and statistics). The narrative is developed to depict real-life events, making it easier for children to connect the concepts to everyday experiences. The book design was then refined based on input from experts and teachers, for example, regarding illustrations, clarity of instructions, and suitability of the content to the child's mathematical literacy level.

Material Scenario:

1. Books with number concepts: Grandma picked apples and put them in the basket. He picked the apples one by one and put them in the basket. While picking apples, children count the apples in the basket, practicing number recognition.
2. Books with statistical concepts: During the classroom learning process, Nana and her friends picked various leaves and counted them. Nana then arranged the leaves by type into a bar chart. Afterward, Nana analyzed the bar chart and compared the differences based on the number of leaves.
3. Books with pattern concepts: Nana and her friends were cycling. Nana noticed the shape of her bicycle tires. After arranging her tires in a specific pattern with her friends', Nana arrived at the park and passed several cars. She saw large and small cars among them and sorted them out.
4. Books about geometry: One bright morning, Nana and her family were having breakfast. Nana looked at the round clock on the wall. Her mother was taking her to school on her bicycle, passing traffic signs, observing the circles on the signs, and counting them.
5. Book about measurement: The holidays have arrived. Nana visited the zoo and walked around with her little brother. She saw her short and tall brothers. She then saw giraffes and zebras of varying heights and measured them. She also many other animals of varying heights.

Formative Evaluation

Prior to child testing, the product was validated by early childhood education experts, mathematics experts, and kindergarten teachers to assess the appropriateness of the content, design, and media presentation. The validation results are presented in Table 2.

Table 2. Expert validation results

The Experts	Percentage	Classification
Early Childhood Education Expert	88. 00	Very good
Mathematics Expert	89.33	Very good
Teacher	81.54	Very good
Average Expert Validation Results	86.26	Very good

Based on the results of product validation by experts, it was concluded that the product falls into the "very good" category and is suitable for further trials and use in classroom learning. In the next phase, a limited trial was conducted in the research to determine the initial responses of children to the active mathematics learning design developed in the form of a picture storybook that includes a variety of contextual mathematics activities. The trial involved 14 children aged 5-6 years from a kindergarten in Riau Province. The learning was conducted directly using the developed media, where the children participated in various activities that combined stories, games, and the manipulation of real objects. The table below is one of the results of expert validation of active mathematics media:

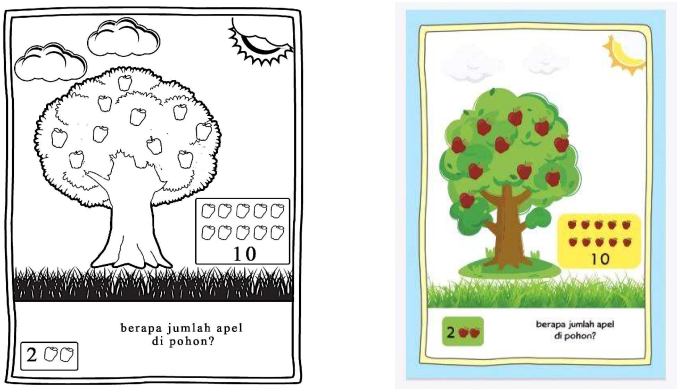
Instructional Revision

limited field trials. The following is an illustration of the design o each active mathematics component for early childhood learning, before and after validation:

Table 3. Results of expert validations

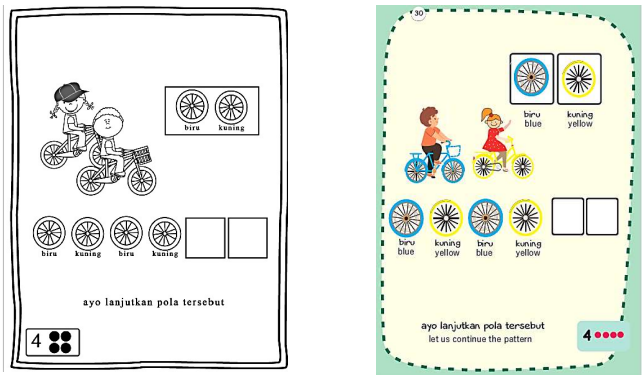
No	Indicator	Factual Score	Ideal Score	%	Category
1	Active mathematics is aligned with the Early Childhood Education (PAUD) curriculum	4	5	80.00%	Eligible
2	Active mathematics is aligned with children's mathematical literacy levels	4	5	80.00%	Eligible
3	Active mathematics is aligned with mathematics content standards	4	5	80.00%	Eligible
4	Active mathematics is aligned with children's play sizes	5	5	100 %	Very Eligible
5	Helps and trains children to recognize mathematics content standards (numbers, patterns, measurement, geometry, and statistics)	5	5	100%	Very Eligible
6	Trains children's hand-eye coordination	5	5	100%	Very Eligible
7	Improves focus and concentration	4	5	80.00%	Eligible
8	Active mathematics is aligned with the children's play scope	4	5	80.00%	Eligible
9	Active mathematics is engaging for children	5	5	100%	Very Eligible
10	Active mathematics is presented in a flexible and clear format	4	5	80.00%	Eligible
11	Active mathematics can be used individually and in groups	5	5	100%	Very Eligible
12	Ease of use of the product (easy to store and transport)	5	5	100%	Very Eligible

13	Time-effectiveness in using active mathematics	4	5	80.00%	Eligible
14	Correctness (Authenticity of the work) and the appropriate size selection of active mathematics media	4	5	80.00%	Eligible
15	Safety (not harmful to children)	4	5	80.00%	Eligible
	Amount	66	75	88.00%	Very Eligible



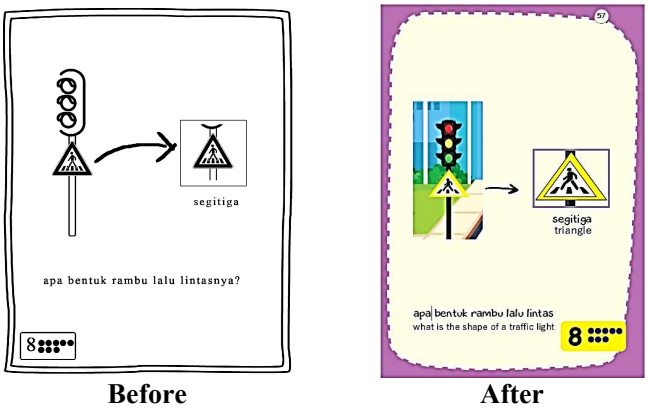
Before **After**

Figure 1. Design of the concept of number mathematics



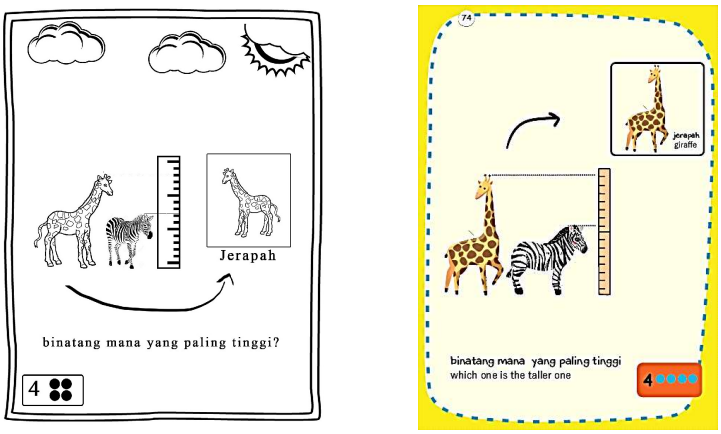
Before **After**

Figure 2. Mathematical concept pattern design



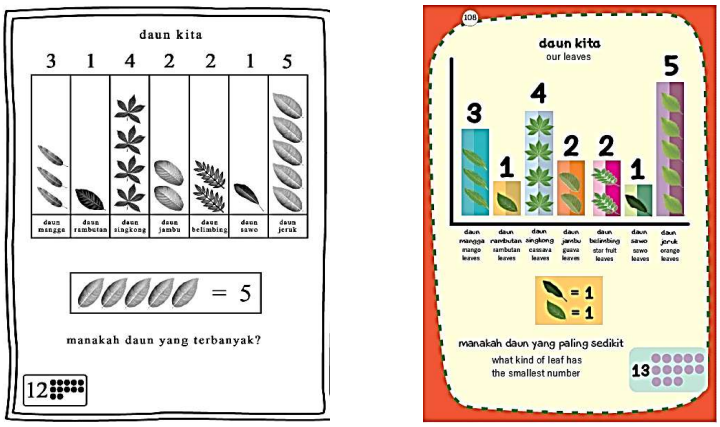
Before **After**

Figure 3. Geometry mathematical concept design



Before **After**

Figure 4. Design of mathematical concept measurement tool



Before **After**

Figure 5. statistical mathematics concept design

Summative Evaluation

Observations during the learning process showed that children responded very positively to active mathematics media. They enthusiastically followed the storyline in the book and actively completed various mathematical tasks presented through play activities. Indicators of children's engagement were evident from their cheerful facial expressions, determination in completing tasks, active participation in answering questions, and following the teacher's instructions. During the use of active mathematics media, children also demonstrated a high level of interest in the provided media, as evidenced by their responses when the active mathematics learning design was presented. Active mathematics media have been proven to facilitate exploration, discussion, and manipulation of real objects, which significantly supports children's understanding of basic mathematical concepts, such as numbers, geometric shapes, patterns, and measurement. For example, through illustrated stories interspersed with activities that involve counting the number of objects in the picture, children not only learn to recognize numbers but also learn to connect them with objects they see directly. The activity of arranging patterns from various colorful shapes also encourages children to understand the sequence and differences of patterns both visually and motorically.

Overall, the results of this limited trial indicate that active mathematics media have strong

potential in creating meaningful learning experiences for young children. The positive responses from children are an early indicator that this media is worthy of further trial. These findings align with the principles of early childhood education (PAUD), which emphasize active involvement, concrete experiences, and a fun and meaningful learning environment. To further strengthen the arguments and results of implementing this active mathematics media, pretests (conducted before the media is presented) and posttests (conducted after the media is presented) were also conducted.

Based on the indicators that have been developed, a pre-test and post-test were conducted in early childhood to assess the results of applying active mathematics media. During the research activities, children showed enthusiasm and a very positive response to the active mathematics media used. Children who had limited mathematical understanding during the pre-test began to show an increase in their mathematical understanding after being assisted by the active mathematics media introduced by the researcher and teacher. Children found it easier to understand various forms of mathematics learning presented with the help of this media, and they quickly grasped concepts such as numbers, patterns, geometry, measurement, and statistics. The results of the trial conducted through the pre-test and post-test of the designed active mathematics media showed that its use can assist teachers in teaching mathematics to children. The table below shows the results of the pre-test and post-test conducted on 14 children in kindergarten:

Table 4. Pretest and posttest results

Indicator	Pre-exam	Post-test
Number	17.857	24
Pattern	20.132	28.1
Geometry	15	23
Measurement	15.071	23
Statistics	19.928	27.9
Average	**17.59**	**25.2**

The study showed an increase in early childhood abilities after the implementation of Active Mathematics media. Pretest and posttest data for each indicator showed a consistent trend, with the average posttest score consistently higher than the pretest score. In the Number indicator, the average score increased from 17.857 in the pretest to 24 in the posttest. There was also an increase in the Pattern indicator, from 20.132 to 28.1. A similar phenomenon was seen in the Geometry indicator, where the score increased from 15 to 23. The Measurement indicator increased from 15.071 to 23, while the Statistics indicator increased from 19.928 to 27.9. Overall, these results suggest that the use of Active Mathematics media effectively enhances early childhood mathematics skills, particularly in mastering numbers, patterns, geometry, measurement, and statistics. This significant increase indicates that interactive and fun media facilitate children's understanding of fundamental mathematical concepts from an early age.

The study's results showed that picture story books based on active mathematical activities significantly improved the mathematical abilities of children aged 5–6 years. The increase in pretest and posttest scores, from 17.59 to 25.20, and the results of the paired samples t-test with a significance value of 0.000 (<0.05), confirmed that this intervention was effective in all indicators of children's mathematics, including numbers, patterns, geometry, measurement, and statistics.

Expert validation yielded an average score of 86.26%, which falls into a very good category. The results of the observations showed that children were enthusiastic, active, and fully engaged during the activity. These findings are consistent with various international studies that emphasize the use of picture books to develop early mathematics skills. Van den Heuvel-Panhuizen, Elia, & Robitzsch (2016) found that using picture books in kindergarten significantly improved children's mathematical understanding. Sasser, Bierman, & Heinrichs (2015) also confirmed that reading storybooks that emphasize mathematical vocabulary can strengthen preschoolers' understanding of number concepts and simple relationships.

Furthermore, the effectiveness of this media is also strengthened by the principle of using concrete manipulatives. Laski, Jor'dan, Daoust, & Murray (2015) explained that manipulatives used in a targeted manner can connect children's concrete experiences with symbolic mathematical representations, thereby deepening conceptual understanding. Through a randomized controlled trial, research by Størksen et al. (2023) also demonstrated that a playful learning curriculum significantly improves pre-mathematics skills in preschool children. This aligns with the results of this study, which shows that manipulative activities in storybooks encourage children to actively construct their knowledge through play experiences.

This study used a one-group pretest-posttest design, which only compares pretest and posttest data. The comparison results are shown in the table below:

Table 5. Normality test results

Indicator	Pre-exam Statistics (Asymp. Sig. (2-tailed)	Post-test Statistics (Asymp. Sig. (2-tailed)
Number	.164 [c]	.184 [c]
Pattern	.200 [c.d]	.200 [c.d]
Geometry	0.060 [c]	0.081 [c]
Measurement	.162 [c]	.179 [c]
Statistics	.200 [c.d]	.200 [c.d]

Based on the results of the *SPSS version 23* test, it is known that the significance of the pretest and posttest for each indicator is greater than 0.05 (N>0.05<N), so it can be concluded that the data is normally distributed.

Based on the data above, the pretest significance of each indicator is greater than 0.05, and the posttest significance of each indicator N is also greater than 0.05. Therefore, it can be concluded that research data are homogeneous.

Table 6. Results of homogeneity test

Indicator	Pre-exam (Asymptomatic Sig.)	Post-test (Assimilation Sig.)
Number	.875	.814
Pattern	.871	.746
Geometry	.677	.677
Measurement	.808	.677
Statistics	.871	.809

Table 7. Hypothesis test (t-Test)

Indicator	Standard Deviation	95% Confidence Interval of the Difference		T	df	Signature (2-tails)
		Lower	Lower			
Number	.24251	-8.06268	-7.66426	108.000	13	.000
Pattern	.26726	-8.22574	-7.91712	113.000	13	.000
Geometry	.26726	-8.08288	-7.77426	111.000	13	.000
Measurement	1.50457	-9.44014	-7.70271	21.316	13	.000
Statistics	.61573	-8.42694	-7.71592	49.048	13	.000

Based on the data above, the calculated t-value obtained for the five components of the mathematics indicators (Numbers, Patterns, Geometry, Measurement, Statistics) is greater than the t-table value of 1.771 and has a significance level of 0.000 < 0.05. It can be concluded that the media used affects the five components of mathematics. Additional evidence also comes from structured interventions in early mathematics learning. Thai, Bang, & Li (2022) demonstrated that a research-based classroom intervention program can accelerate children's mathematical development early. Similarly, Outhwaite, Faulder, Gulliford, & Pitchford (2019) found that using an interactive, activity-based app significantly improved preschoolers' mathematics achievement. These findings confirm that systematically and contextually designed interventions, such as activity-based picture storybooks, cn produce meaningful learning gains.

Theoretically, the success of this product can also be explained through the Dick & Carey model of instructional development, which emphasizes the importance of needs analysis, goal setting, instruction development, expert validation, and field trials. This systematic development model is proven relevant to the findings of Laski et al. (2015) and is also supported by meta-analytic evidence highlighting the importance of teacher planning and guidance in the effectiveness of learning media.

Thus, the results of this study support previous empirical findings and provide a practical contribution by providing innovative media alternatives for early childhood education teachers. Picture storybooks based on active mathematical activities can be seen as a creative solution to strengthening the mathematical foundations of early childhood through enjoyable, contextual, and meaningful learning.

■ CONCLUSION

Based on the results and discussion, the following conclusions can be drawn: (1) The results of the normality and homogeneity tests indicate that the product usage data meet the requirements of normal distribution and are homogeneous; thus, the media developed can be said to be consistent and can be used on a wide scale. Validation was provided by early childhood education experts, mathematics experts, and kindergarten teachers as users; (2) This shows that the Active Mathematics product developed is considered suitable for use in learning; (3) The application of this media in limited trials shows an increase in children's mathematical abilities, marked by positive responses from observers and approval from research subjects; (4) Children's positive responses are clearly visible when Active Mathematics is applied during the mathematics learning process in class.

Therefore, the Active Mathematics learning design for early childhood was developed through a series of stages that meet the indicators of validity, practicality, and effectiveness. This design comprises several key components, including a mathematics lesson plan, a picture storybook designed to incorporate various mathematical problem situations that children can solve, and a special guidebook intended for kindergarten

teachers to facilitate optimal learning. Active involvement of children in the mathematics learning process is believed to be more meaningful because children are directly able to solve problems presented through fun games (Liwis, Antara, & Ujianti, 2017). This has been proven to help teachers manage a more meaningful and enjoyable mathematics learning process for early childhood. By implementing this approach, children are able to show interest, enthusiasm, and a better understanding of basic mathematical concepts.

The use of story-based media and concrete games appropriate for children is key to fostering their active engagement during the learning process. In line with these conclusions, there are several practical recommendations for educators and researchers interested in developing or implementing Active Mathematics designs. First, the application of this learning design is still limited and has not been widely adopted in early childhood education institutions. Therefore, it is highly recommended that teachers and researchers attempt to adapt and implement this design in more educational settings, particularly in kindergartens, to obtain a more comprehensive understanding of its effectiveness. The results of this development can then serve as a reference in designing other learning innovations that still consider children's potential and cognitive development. Second, kindergarten teachers who wish to implement Active Math-based mathematics learning are advised to develop learning designs independently, adapting them to the characteristics, needs, and developmental levels of the children. These designs should also adhere to appropriate mathematics content standards for early childhood. Teachers can also utilize Active Math media, developed by researchers, as learning aids for children in the classroom. Third, in efforts to improve children's mathematical thinking skills, such as problem-solving, learning interest, motivation, and self-confidence, the Active Mathematics approach can be an effective alternative. Implementing this design has the potential to provide a learning experience that is not only enjoyable but also optimally hones children's basic skills.

Mathematics is often regarded as the most challenging and intimidating subject for students in Indonesia. This stigma is felt by almost all students at every level of education, partly due to the monotonous learning system and the lack of media used to make mathematics learning interesting and enjoyable for young children (Rohibni, Rokhmawan, Sayer, & Fitriyah, 2022). Mathematics is considered a complex and complicated field of study, leading some children to feel that this concept should be avoided (Keith, 2017). Therefore, it is necessary to redesign mathematics learning so that children do not feel burdened when playing and learning standard mathematics content. Active mathematics learning designs offer opportunities for children to engage actively in problem-solving and manipulation (Vale & Barbosa, 2023). In other words, children will be actively involved in fun play activities, making mathematics learning more meaningful and more likely be retained in their memories for a long time.

■ REFERENCES

Breive, S. (2020). The materialisation of children's mathematical thinking through organisation of turn-taking in small group interactions in kindergarten. In *Mathematics Education in the Early Years* (pp. 281–299). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-34776-5_17

Chang, C., Wu, S., Chang, Y.-L., & Chang, L. A. (2024). *Designing and implementing sustainable professional development programs/ : embodied curriculum and instruction for kindergarten teachers*.

Charlesworth, R. (2016). *Math and science for young children* (8th ed.). Boston: Cengag Learning.

Fayrus, & Slamet, A. (2022). *Model penelitian pengembangan (R n D)*. Malang: Institut Agama Islam Sunan Kalijogo Malang

Redaksi:

Hornburg, C. B., Borriello, G. A., Kung, M., Lin, J., Litkowski, E., Cosso, J., … Purpura, D. J. (2021). Next directions in measurement of the home mathematics environment: An international and interdisciplinary perspective. *Journal of Numerical Cognition*, *7*(2), 195–220. https://doi.org/10.5964/jnc.6143

Hunter, J., & Miller, J. (2022). The use of cultural contexts for patterning tasks: supporting young diverse students to identify structures and generalise. *ZDM – Mathematics Education*, *54*(6), 1349–1362. https://doi.org/10.1007/s11858-022-01386-y

Keith, L. (2017). Developing young children's mathematical learning outdoors: linking pedagogy and practice. In *Developing Young Children's Mathematical Learning Outdoors: Linking Pedagogy and Practice*. https://doi.org/10.4324/9781315300672

Koderi, K., Kuswanto, C. W., & Nuryati, S. (202s1). *Meningkatkan kognitif anak usia dini melalui pengembangan media cube learning* [Improving early childhood cognitive skills through cube learning media development]. *Jurnal Obsesi/ : Jurnal Pendidikan Anak Usia Dini*, *6*(3), 1834–1845. https://doi.org/10.31004/obsesi.v6i3.1824

Laski, E. V., Jor'dan, J. R., Daoust, C., & Murray, A. K. (2015). What makes mathematics manipulatives effective? lessons from cognitive science and montessori education. *Sage Open*, *5*(2). https://doi.org/10.1177/21582440155895

Liwis, Antara, & Ujianti. (2017). *Pengaruh model pembelajaran matematika realistik terhadap kemampuan mengenal konsep bilangan pada anak kelompok a taman kanak-kanak gugus v kecamatan buleleng* [The influence of realistic mathematics learning model on the ability to recognize number concepts in group a children of kindergarten cluster v, buleleng district]. *E-Journal Pendidikan Anak Usia Dini Universitas Pendidikan Ganesha*, *5*(1), 116–126.

Macdonald, K., Milne, N., Pope, R., & Orr, R. (2022). Evaluation of a 12-week classroom-based gross motor program designed to enhance motor proficiency, mathematics and reading outcomes of year 1 school children: a pilot study. *Early Childhood Education Journal*, *50*(5), 811–822. https://doi.org/10.1007/s10643-021-01199-w

Montague-Smith, A., Cotton, T., Hansen, A., & Price, A. J. (2018). *Mathematics in early years education* (4th ed.). Abingdon: Routledge.

Nugrahani, R., & Permata, R. D. (2021). *Validasi media buku lift the flap untuk pembelajaran*. *6*(1), 691–696.

Outhwaite, L. A., Aunio, P., Leung, J. K. Y., & Van Herwegen, J. (2024). Measuring mathematical skills in early childhood: a systematic review of the psychometric properties of early maths assessments and screeners. In *Educational Psychology Review* (Vol. 36). Springer US. https://doi.org/10.1007/s10648-024-09950-6

Outhwaite, L. A., Faulder, M., Gulliford, A., & Pitchford, N. J. (2019). Raising early achievement in math with interactive apps: A randomized control trial. *Journal of Educational Psychology*, *111*(2), 284–298. https://doi.org/10.1037/edu0000286

Parviainen, P., Eklund, K., Koivula, M., Liinamaa, T., & Rutanen, N. (2023). Teaching early mathematical skills to 3- to 7-year-old children differences related to mathematical skill category, children's age group and teachers' characteristics. *International Journal of Science and Mathematics Education*, *21*(7), 1961–1983. https://doi.org/10.1007/s10763-022-10341-y

Raharjo, I., Rasiman, & Untari, M. F. A. (2021).

Faktor kesulitan belajar matematika ditinjau dari peserta didik [Factors contributing to students' difficulties in learning mathematics]. *Journal for Lesson and Learning Studies*, *4*(1), 96–101.

Rohibni, R., Rokhmawan, T., Sayer, I. M., & Fitriyah, L. (2022). The variety of mathematics learning media for early childhood in improving basic mathematics ability. *Bulletin of Science Education*, *2*(3), 102. https://doi.org/10.51278/bse.v2i3.427

Sasser, T. R., Bierman, K. L., & Heinrichs, B. (2015). Executive functioning and school adjustment: The mediational role of pre-kindergarten learning-related behaviors. *Early Childhood Research Quarterly*, *30*, 70–79. https://doi.org/10.1016/j.ecresq.2014.09.001

Solfiah, Y. (2022). *Games edukatif berbasis android untuk meningkatkan kemam puan mengenal angka anak usia dini*. *6*(3), 2146–2158. https://doi.org/10.31004/obsesi.v6i3.910

Stalchenko, N., Vanhala, A., Korhonen, J., & Aunio, P. (2023). The association between physical activity during preschool hours and early numeracy. *Journal of Early Childhood Education Research*, *12*(3), 278–305. https://doi.org/10.58955/jecer.127930

Størksen, I., Rege, M., Solli, I. F., ten Braak, D., Lenes, R., & Geldhof, G. J. (2023). The playful learning curriculum: A randomized controlled trial. *Early Childhood Research Quarterly*, *64*, 36–46. https://doi.org/10.1016/j.ecresq.2023

Thai, K.-P., Bang, H. J., & Li, L. (2022). Accelerating early math learning with research-based personalized learning games: a cluster randomized controlled trial. *Journal of Research on Educational Effectiveness*, *15*(1), 28–51. https://doi.org/10.1080/19345747.2021.1969710

Torres-Peña, R. C., Peña-González, D., & Ariza-Echeverri, E. A. (2025). Mathematical thinking in preschool: strengthening seriation and counting through problem solving. *International Journal of Early Childhood*, *57*(2), 379–401. https://doi.org/10.1007/s13158-024-00402-4

Tzekaki, M. (2020). Mathematical activity in early childhood and the role of generalization. In *Mathematics Education in the Early Years* (pp. 301–313). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-34776-5_18

Vale, I., & Barbosa, A. (2023). Active learning strategies for an effective mathematics teaching and learning. *European Journal of Science and Mathematics Education*, *11*(3), 573–588. https://doi.org/10.30935/scimath/13135

Van den Heuvel-Panhuizen, M., Elia, I., & Robitzsch, A. (2016). Effects of reading picture books on kindergartners' mathematics performance. *Educational Psychology*, *36*(2), 323–346. https://doi.org/10.1080/01443410.2014.963029

Veraksa, N., Sheridan, S., & Colliver, Y. (2023). Balancing child-centred with teacher-directed approaches to early education: Incorporating young children's perspectives. *Pedagogy, Culture & Society*, *31*(5), 915–932. https://doi.org/10.1080/14681366.2021.1955736

Zummiasa, Armia, V., Mas'udah, Widayati, S., & Reza, M. (2023). P*engembangan media lift the flap book untuk meningkatkan kemampuan konsep penjumlahan 1-5 pada anak usia dini* [Development of lift the flap book media to improve the concept of addition 1-5 in early childhood]. *Program Studi PGRA*, *9*(1), 66–78.