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Development of Montessori-Based Teaching Aid to Enhance Arithmetic Skills for First-Grade Students at MI Al-Maarif 02 Singosari, Kabupaten Malang

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Abstract

This study aimed to develop a Montessori-based teaching and learning aid to help first-grade students to understand better the concepts of addition and subtraction. The research employed a Research and Development (R&D) method with the Borg and Gall model, adapted to six stages: research and data collection, planning, initial product development, preliminary field testing, product revision, and main field testing. Product validation was conducted by experts in content, media, and pedagogy, showing that the aid being developed was highly valid for classroom use. Field trials at MI Al-Maarif 02 Singosari, using a pre-test and post-test design, demonstrated a significant improvement in students' arithmetic skills, with average scores increasing from 70.34 to 94.83. The N-gain analysis showed a score of 0.78, indicating high effectiveness of the learning tool in enhancing students' abilities. This study suggested that the Montessori-based teaching and learning aid significantly improved students' understanding of basic mathematical concepts in a fun and comprehensible way.

Keywords: *Montessori learning aid; validity and effectiveness; elementary schools; arithmetic skills*

INTRODUCTION

Learning is a process that involves active interaction between students, teachers, and various available learning resources. In order for the learning process to be effective and comprehensive, the use of appropriate learning media is essential (Batubara, 2020). The right learning media can help present the material more clearly and engagingly, enriching students' learning experiences and making it easier for them to understand the concepts being taught. Furthermore, learning media also supports teachers in managing the class and delivering information more efficiently, ultimately contributing to better learning outcomes. Therefore, selecting media that align with the learning needs is crucial to achieving optimal educational outcomes (Islami et al., 2022).

In this context, the Montessori approach offers an urgent and valuable perspective. Maria Montessori emphasized the importance of an environment that supports independent learning through exploration and hands-on experiences. In a Montessori classroom, learning media are not just tools for communication but also become part of the learning process itself, encouraging students to take initiative, explore, and learn at their own pace. This approach fosters self-directed learning and critical thinking, which aligns well with modern educational goals. Furthermore, Montessori education prioritizes personalized learning, enabling children to grow into responsible global citizens and continuous learners throughout their lives (Saha & Adhikari, 2023). By empowering students to take ownership of their learning, the Montessori method helps develop lifelong skills that are crucial in an ever-evolving world.

Although the importance of learning media in enhancing students' understanding and engagement is clear, there is a noticeable gap in the application of these tools across different educational settings, particularly in their ability to promote independent learning and critical thinking. On the other hand, the Montessori approach, which prioritizes self-directed learning and hands-on experiences, has proven to be more effective in improving students' understanding compared to conventional approaches. Aziza et al. (2020) found that the Montessori approach, with its focus on self-exploration, project-based learning, and the use of supporting learning media, significantly enhances students' understanding compared to conventional methods that are more teacher-centered. This approach provides students with more opportunities to explore the material and develop their critical thinking skills. The integration of learning media in the Montessori method not only supports a deeper understanding of concepts but also fosters active student engagement, which is crucial in developing their cognitive and social skills. Therefore, the application of the Montessori method, supported by appropriate learning media, offers an effective solution to address gaps in education, while also preparing students to become responsible lifelong learners.

The use of learning media not only enhances students' understanding but also motivates them to be more actively involved in learning activities. According to Islami et al. (2022), learning media has a significant psychological impact on students, increasing their participation in the learning process. The right media also encourages creativity, problem-solving skills, and interaction with the material, creating a dynamic and inclusive learning environment. By offering various types of media that suit students' learning styles-whether visual, auditory, or kinesthetic—learning media helps develop students' cognitive and social abilities more comprehensively.

This is especially important in subjects like mathematics, where abstract concepts and problem-solving techniques are central. Learning media can make mathematical concepts more tangible and easier to understand, enabling students to develop the critical thinking skills needed. At the elementary school level, the right media can help students understand fundamental mathematical concepts such as addition and subtraction in a more concrete way. According to Rismawati & Khairiati (2020), the use of media in mathematics learning can clarify abstract concepts and improve students' understanding of the material being taught.

Additionally, using media such as addition and subtraction beads can transform abstract mathematical concepts into more tangible objects that are easier to understand. This helps students develop analytical and problem-solving skills while encouraging them to be more actively involved in the learning process. The use of various types of media not only supports different learning preferences but also helps students remember and apply new knowledge more effectively (Purba et al., 2020). Therefore, learning media plays a crucial role in creating engaging and effective learning experiences, helping students gain a deeper understanding of mathematical concepts.

In conclusion, it can be said that the integration of appropriate learning media is essential in the process of learning mathematics, particularly in helping students understand fundamental concepts such as addition and subtraction. The use of suitable media can facilitate students' understanding and enhance their critical thinking skills, which will ultimately support the achievement of optimal educational goals (Syahputri, 2018).

According to Mashuri (2019), instructional media are designed tools or materials used in the learning process to communicate information to students. These media not only convey knowledge but also stimulate students' thoughts, feelings, interests, and attention. By engaging students, teaching aids contribute to creating an effective learning environment. Their primary function is to enhance communication between teachers and students, which ultimately improves learning outcomes. This interaction through media helps to enhance students' comprehension and retention of material, fostering more successful educational experiences.

Teaching aids are essential for improving the quality of learning by facilitating effective communication between teachers and students (Kustandi & Darmawan, 2020). They bridge the gap between abstract concepts and students' understanding, using media such as images, charts, videos, and manipulatives. These tools help teachers present lessons in a more structured and visually engaging way, making complex ideas more comprehensible.

Moreover, teaching aids spark students' interest and motivation, making the learning process more engaging and meaningful. According to Hasan et al. (2021), incorporating visual, auditory, and interactive elements into lessons captures students' attention and supports diverse learning styles, which is essential for maintaining classroom engagement. Teaching aids increase participation and promote active learning, helping students connect more deeply with the material and enhancing both their enjoyment and academic performance.

Teaching aids also play a critical role in ensuring the success of educational programs. Juhaeni et al. (2020) emphasizes that these tools help students better grasp key concepts while encouraging active participation. They bridge the gap between teacher-led instruction and student comprehension, fostering a more dynamic and interactive learning environment. By improving understanding and maintaining student interest, teaching aids significantly contribute to the success of educational initiatives.

The functions of teaching aids are multifaceted and essential for effective learning. Sumiharsono & Hasanah (2017) state that teaching aids help build an effective learning environment by clarifying complex material and facilitating a clearer understanding of content. These tools cater to different learning styles, helping students grasp both simple and complex concepts more easily, and improving the overall quality of teaching and learning.

Additionally, teaching aids enhance both teaching and student comprehension. Ramli (2012) highlights that teaching aids allow teachers to organize and structure the learning process more efficiently, delivering content in a more coherent manner. For students, these tools provide alternative ways to engage with the material, especially when dealing with abstract concepts. By bridging the gap between theory and practice, teaching aids empower students to understand and retain information more effectively.

In terms of acceptability, teaching aids must meet certain criteria to be effective. Arista and Arista & Pratiwi (2017) identify four key aspects: usefulness, feasibility, accuracy, and appropriateness. The media should meet the needs of the classroom and support learning goals while presenting clear, accurate information that is easy to use. Additionally, the relevance of the material, emotional impact on students, and ease of navigation are important factors. Ernawati et al. (n.d.) stresses the importance of pedagogical alignment and technical stability in ensuring the effectiveness of teaching aids.

Finally, addition is a fundamental mathematical operation in which two or more numbers are combined to obtain a sum. The numbers being added are called "addends," and the operation is represented by the plus sign (+). For example, in the expression $3 + 1 = 4$, 3 and 1 are the addends, and their sum is 4. Addition forms the basis for more complex mathematical operations.

Key principles of addition include the Commutative Property, which states that the order of addends does not affect the sum ($a + b = b + a$), the Associative Property, which asserts that the grouping of numbers does not change the result ($(a + b) + c = a + (b + c)$), and the Identity Property, which indicates that adding zero to a number does not alter its value ($a + 0 = a$). These principles about addition in mathematics are fundamental to be understood (Siregar, 2023).

The research title "Development of Montessori-Based Addition Teaching Aid to Enhance Arithmetic Skills of First-Grade Students at MI Al-Maarif 02 Singosari, Kabupaten Malang" was chosen based on the importance of using appropriate learning media to support understanding in mathematics, particularly in the concept of addition for first-grade students. The Montessori approach, which emphasizes self-directed learning and hands-on experiences, is highly relevant for helping students develop their arithmetic skills. Montessori-based learning media can facilitate a more concrete and interactive understanding of the concept of addition, in line with the Montessori principles that support student initiative and exploration. By utilizing appropriate learning tools, this research aimed to enhance student engagement and strengthen their cognitive skills in mathematics, improve their learning outcomes, and prepare them to be lifelong learners.

METHODS

The ADDIE development model was used in this study. ADDIE consists of five sequential stages: Analysis, Design, Development, Implementation, and Evaluation, with the aim of improving the quality and effectiveness of the development of the product or item being analyzed. The researcher chose ADDIE because this model could outline the basic steps in designing a simple learning system (Cahyadi, 2019). This helped to ensure a more organized and effective development process to achieve the desired learning outcomes.

This study involved several testing phases, including expert validation and field testing. The developed product was validated to ensure it met the feasibility standards for both content and design (Azizi, 2021). Expert validation was conducted considering the content, media, and pedagogy specialists, followed by field trials at MI Al-Maarif 02

Singosari. The field testing used one-group pre-test and post-test design experiment, comparing students' arithmetic skills before and after using the teaching aid. This design aimed to assess improvements in students' mathematical abilities following the use of the educational tool. The experimental design used is shown in the following table.

Table 1. One-Group Pre-Test and Post-Test Design Experiment

Pretest (Initial Test)	Treatment	Posttest (Final Test)
O_1	X	O_2

Explanation:

O1 : Pre-test before treatment

X : Treatment (the use of the teaching aid in the lesson)

O2 : Post-test after treatment

This study employed both qualitative and quantitative data analysis to assess the validity and effectiveness of the teaching media. For qualitative analysis, the Miles and Huberman model was applied, following the steps; data collection, data reduction, data presentation, and drawing conclusions. In the quantitative analysis, validity and reliability tests were conducted using SPSS, with Cronbach's Alpha reliability formula. The validity of the media was evaluated using a questionnaire, and the validity score was calculated using the following formula.

$$P = \frac{f}{N} x100$$

P is the final score, f is the score obtained, and N is the maximum score. The validity results were then categorized according to the following criteria.

Table 2. Product Validity Criteria

Score	**Criteria**
81-100	Very Valid
60-80	Valid
40-60	Sufficiently Valid
20-40	Less Valid
0-20	Invalid

After testing the media's validity, its effectiveness was measured through a pre-test-post-test evaluation using a one-group pretest-posttest design. Statistical analysis included normality testing using Kolmogorov-Smirnov, homogeneity testing using Bartlett's test, linearity testing to determine the relationship between variables, and t-tests to examine the research hypothesis regarding the improvement of students' arithmetic abilities after using the Montessori-based teaching aids.

RESULTS AND DISCUSSION

Development Process of the Addition Teaching Aid

This study focused on developing an additional learning aid for first-grade students at MI Al-Maarif 02 Singosari, to address the specific challenges students face in their learning process. The research began with a series of interviews with first-grade teachers to identify the most pressing issues affecting the students' mathematical understanding. The teachers reported that the students had difficulty engaging with the material due to limited instructional resources, with most of the available materials were only worksheets and modules. Furthermore, the teaching method was largely lecture-based, leading to disengagement and limited hands-on learning opportunities. This feedback provided valuable insights into the challenges that needed to be addressed by developing new learning tools.

The development procedure consists of several stages, which include:

1. Analysis

In the analysis stage, the researcher engaged in two essential activities: identifying problems and understanding student needs (Budoya et al., 2019). To gather the necessary information, the researcher posed several questions related to the students' conditions and chose one of the class teachers as a method of data collection.

In this initial phase, the study sought to understand the obstacles in which teachers and students faced in the classroom. The lack of engaging was identified as a key factor that hindered effective learning, particularly in subjects like mathematics. This highlighted the need for innovative teaching aids to capture students' attention better and facilitate active learning. Teachers' feedback was crucial in pinpointing these challenges and helped shape the direction for developing more effective learning tools for the students.

The findings from these interviews highlighted that there was a lack of interactive, hands-on teaching aids in the classroom, which hindered the students' ability to visualize and understand mathematical concepts, particularly addition. To tackle these challenges, the researcher created an interactive additional teaching and learning aid that would provide students with a tangible, engaging way to learn basic mathematic operations. The aid was specifically designed to help students perform addition operation with numbers up to 20, making it suitable for first-grade learners. By incorporating concrete objects into the learning process, the goal was to help students better understand the concept of addition operation through direct manipulation and visual representation, which was particularly effective for young learners who were still developing their cognitive abilities.

This finding emphasized the importance of kinesthetic learning—where students learned through movement and interaction with physical objects. Such hands-on approaches could be especially beneficial for younger children, as they helped bridge the gap between abstract mathematical concepts and real-world applications. The development of the interactive additional teaching aid was a direct response to this need, offering a more tangible and engaging way to introduce basic math concepts. This approach also leveraged students' natural curiosity and energy, allowing them to physically manipulate objects as they learn, which could enhance their understanding and retention of the material.

2. Design

The design phase included activities such as designing by feature, as well as instructional and process tasks like setting learning objectives, specifying instructional strategies, designing subject content, and creating class diagrams (Budoya et al., 2019). In this stage, the researcher formulated solutions aimed at addressing the issue of students' limited arithmetic skills at Madrasah Ibtidaiyah (MI) Al Ma'arif Singosari. The expected product to be developed was a teaching aid that could assist in learning addition and subtraction. The development focus included content, components of the teaching aid, materials, size, design, and usage instructions. The addition and subtraction content presented in this product was based on the material taught at school. The media components used included:

a. A board measuring 40 x 20 cm, made from plywood, shaped like a chessboard
b. 150 orange beads
c. Number blocks made from acrylic material for stability and durability.
d. A user guide printed on 150-gram art paper in A5 size, which is practical for shipping or storage. The researcher used the Canva application to assist in creating an effective and engaging design for the product. An attractive and effective design was necessary to highlight the appeal of the addition and subtraction tools created to assist students at MI Al Ma'arif Singosari.

The design of the counting aid considered both the students' needs and the learning objectives for first-grade math. During the planning phase, the researcher worked on developing the structure and components of the aid. The counting tool was crafted from plywood, measuring 68 x 45 cm, with 10 horizontal and 5 vertical holes for counting. These holes allowed for objects' easily to take place and move, which was used for counting and performing addition operations. The design was intentionally simple but effective, with each component serving a clear educational purpose. The researcher ensured that the materials chosen were durable, safe for young children, and visually appealing to keep the students engaged during lessons.

The design phase was crucial in ensuring that the learning aid would be both functional and safe for young children. The choice of materials, such as plywood, ensured durability, while the specific measurements and hole placements allowed for easy manipulation of objects, which was essential for hands-on learning. Moreover, the visual appeal of the tool was an important factor in maintaining student interest and motivation during lessons. By ensuring the materials as safe and aesthetically pleasing, the researcher aimed to create a tool that would capture the students' attention while serving its educational purpose.

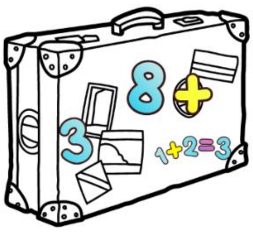
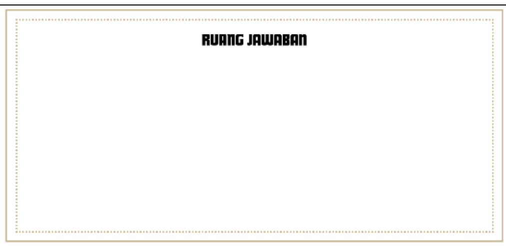
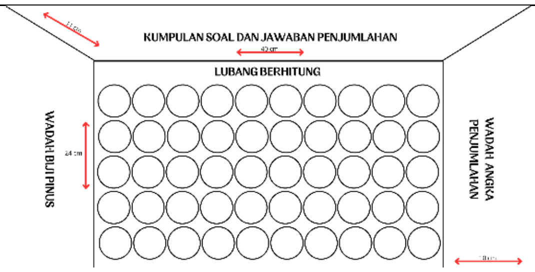
In addition, to the main counting frame, the learning aid included several key components designed to facilitate the learning process. These included containers for storing palm seeds for counting objects and magnetic number cards that students could move around the counting board. A wooden mallet was also included to help students physically manipulate the components, adding an interactive element to the activity. Furthermore, question-and-answer cards were created to guide students through the learning process, allowing them to practice addition problems in a structured, step-by-step manner. These materials were carefully selected to ensure that the students could easily use them while also being sufficiently engaging to maintain their attention.

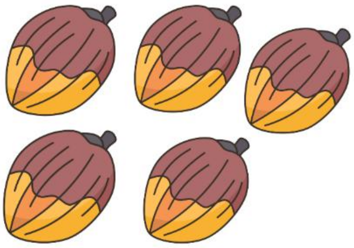
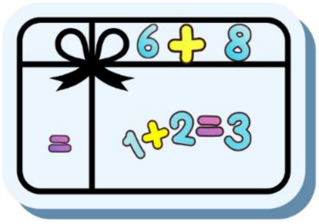
By incorporating various materials like seeds, magnetic numbers, and mallets, the learning aid created multiple ways for students to engage with the content. These components helped address different learning styles, ensuring that every student could participate meaningfully. The containers and mallets provided tactile experiences, while the magnetic number cards allowed students to manipulate the numbers visually. Additionally, including question-and-answer cards allowed for guided practice, ensuring students had a structured way to reinforce their learning. This multi-sensory approach ensured that the tool was both engaging and effective in promoting active participation.

To organize the development of the addition aid, the researcher created a detailed storyboard that outlined how each component would function within the learning process. This storyboard provided a clear plan for arranging and using each item in the counting aid, ensuring that the materials worked cohesively to support the students' learning objectives. The storyboard, which was presented in Table 4 of the study, showed how the components were arranged to facilitate the understanding of addition. Each component had a specific role in helping students grasp the concept of addition and build the foundational skills needed for further mathematical learning. This thoughtful planning ensured that the addition aid would be both functional and effective in improving the students' mathematical skills.

The use of a storyboard was a strategic step in ensuring that the learning aid would be used effectively. By mapping out how each component would be integrated into the teaching process, the researcher ensured that the tool would not only be educationally sound but also easy to use in the classroom. The storyboard served as a guide for teachers to understand how each part of the tool would contribute to the learning process, providing a structured way to implement the aid in lessons. This structured approach ensured that all components served a clear pedagogical purpose, leading to a more focused and goal-oriented learning experience for the students.

Table 4. Storyboard of the Counting Aid Design

No.	Component	Description
1.	 Addition Aid	The counting aid, when closed, with all components stored inside.
2.	 Answer Area	Used to place magnetic answers for the addition questions (58 x 35 cm).
3.	 a. Counting Holes, b. Card Storage, Mallet	a. Counting holes: 63 cm wide, 40 cm long. b. Storage for question cards, answer cards, and mallet: 40 cm wide, 8.5 cm long.

4.	 Mallet	A wooden mallet, finished with lacquer to make it visually appealing.
5.	 Palm Seeds	120 palm seeds, used in addition operations, painted to attract students' attention.
6.	 Question and answer card	10 question and answer cards (8 x 11 cm, art paper 260gsm) with an attractive design.
7.	 Instruction Manual	A printed guide with instructions for using the counting aid, made from art paper.

Source: Private Document

3. Development

The development phase included several activities, such as creating and assembling all the content and components based on the design phase, constructing the structure of the addition teaching aid, and making the teaching aid accessible (Budoya et al., 2019). In this stage, all product components were worked on and integrated to form a complete product, according to the plan made at the design stage. Additionally, the product undergone testing and validation by media experts, subject matter experts, and learning specialists (Faizah et al., 2022). The validation process ensured the product's validity in two key aspects: content and design feasibility (Azizi, 2021). This step was taken to ensure that the product was an effective and satisfactory learning aid for students.

Once the design of the addition learning aid was finalized, the next step in the development process was to let the product to an initial validation by a panel of experts. These experts included professionals with knowledge in three key areas: content, teaching aids, and learning methods. Their role was to evaluate the developed teaching aid's effectiveness in achieving educational goals, its relevance to the needs of first-grade students, and its overall quality. The validation process aimed to ensure that the tool was pedagogically sound and aligned with the learning objectives for teaching addition. Each expert reviewed the aid's design, functionality, and content to determine whether it met the necessary criteria for successful implementation in the classroom.

The validation by experts was an essential step to ensure that the additional teaching and learning aid was both educationally sound and practically effective. By involving specialists in the fields of content, teaching aids, and learning methods, the research ensured that the tool would be evaluated from a variety of critical perspectives. This rigorous validation process was designed to verify that the aid would meet the learning goals for first-grade students, be appropriate for the classroom setting, and effectively address the challenges identified in earlier phases of the study. The expert panel's input was vital to ensure that the aid was well-aligned with the best practices in education.

The results from the expert evaluations were highly favorable, as reflected in the validation scores presented in Table 4. The experts unanimously agreed that the addition aid was well-constructed and highly valid for use in an educational setting. The product received positive feedback regarding its suitability for first-grade learners, with the experts noting that the interactive nature of the tool, combined with its concrete materials, made it an effective way to teach addition formulas. The tool was praised for its clear design, ability to engage young students, and potential to enhance understanding of addition concepts. The validation indicated that the product met the necessary educational content and user experience standards.

The validation results confirmed that this aid was both practical and effective for the target audience. The experts' unanimous approval highlighted that the tool met the educational criteria necessary for teaching first-grade students. Positive feedback on the tool’s interactivity and use of concrete materials underscored its effectiveness in making abstract concepts like addition concept became more accessible to young learners. The evaluation affirmed that this aid was not only educationally appropriate but also engaging and capable of enhancing students' understanding of key mathematical concepts. This validation helped ensure that the aid was ready for implementation in real-world classrooms.

Following the expert validation, the next step was to revise the product based on the feedback provided. These revisions aimed to address any minor issues or improvements suggested by the experts to optimize the aid's effectiveness for further ussage.a After incorporating the necessary changes, field trials were conducted with first-grade students to test the real-world effectiveness of the additional aid. These trials were essential for assessing how well the students could engage with and benefit from the tool in the classroom. The feedback from the field trials would be used to make any additional adjustments, ensuring that the aid effectively enhanced students' understanding of addition concept and met the learning objectives which were already set out.

After the expert validation, the next logical step was to refine the tool based on the insights and suggestions provided. This iterative process of revision ensured that the addition aid was continually improved and fine-tuned to meet its educational goals. The field trials were crucial to test the tool's practical application in a classroom environment. These trials allowed the researchers to observe how students interacted with the aid, how effectively it helped them learn addition, and whether there were any unforeseen challenges in its use. The feedback from these trials would guide further refinements, ensuring that the aid was as effective and user-friendly as possible before it was fully implemented in the classroom.

Table 4. Validator Assessment Results

No.	Validator	Score	Description
1.	Content Expert	98.6	Very Valid
2.	Teaching Aid Expert	97.3	Very Valid
3.	Learning Expert	96.0	Very Valid

Table 4 presented the results of the validation assessment conducted by three experts: a content expert, a teaching aid expert, and a learning expert. Each expert evaluated the addition learning aid based on their area of expertise, with the content expert focusing on the accuracy and appropriateness of the mathematical content, the teaching aid expert assessing the design and functionality of the tool, and the learning expert evaluating its pedagogical value and effectiveness in supporting student learning. The scores from all three experts were exceptionally high, indicating that the tool was deemed very valid in each of these important areas.

The content expert scored the highest 98.6, classifying the addition aid as "very valid." This score reflected the expert's assessment that the mathematical content incorporated in the tool was accurate, aligned with the first-grade curriculum, and suitable for students' cognitive development. Similarly, the teaching aid expert awarded a score of 97.3, also classifying the tool as "very valid." This high score highlighted that the design and materials used in the aid were effective, functional, and engaging, making the tool appropriate for classroom use. The teaching aid expert also likely appreciated how the tool could facilitate hands-on learning, which crucial for young students.

Finally, the learning expert gave the addition aid a score of 96.0, also rating it as "very valid." This suggested that the tool was seen as a valuable educational resource, capable of enhancing students' understanding of addition through interactive and concrete learning experiences. The positive evaluations from all three experts indicated that the additional teaching and learning aid was well-designed, pedagogically sound, and ready for practical implementation. Based on these results, the tool was considered suitable for further testing in a real classroom setting to assess its effectiveness in improving students' mathematical skills.

The teaching aid was also validated by a learning expert validator. According to the result of validation, the teaching aid developed received a high score of 96.0, indicating its strong alignment with learning objectives and students' cognitive abilities. The expert praised the tool for effectively helping students understand the addition concept and formulas, engaging them in both individual and group learning. The clear user manual was also highlighted to enable students to operate the tool independently. Although the aid was well-received, the expert suggested replacing the wooden mallet with a safer plastic version to enhance student safety, without requiring major revisions. The feedback confirmed the tool's effectiveness while offering a valuable safety improvement.

4. Implementation

The implementation phase was a crucial stage in the application of a newly developed teaching aid in the classroom. According to Budoya et al. (2019), this phase involved integrating the newly developed teaching aid into a real-world classroom setting, ensuring it can be effectively used by both the teacher and students. In this phase, the teaching aid was applied directly in the classroom to ensure its compatibility with the actual learning environment and the needs of both the teacher and students. Additionally, ongoing support and guidance were provided to the teacher and students to ensure the teaching aid was utilized effectively and to address any issues that might arise during the learning process.

A pre-test was administered to MI Al-Maarif 02 Singosari students before implementing the learning media to assess their ability in solving abstract problems without visual aids. The results, with an average score of 70.34, revealed that while students understood basic addition concept, they struggled with abstract problems. This baseline data highlighted the need for additional support, particularly in solving problems without visual cues, and set the stage for introducing the Montessori-based addition aid. It also served as a benchmark for evaluating the impact of the learning aid after its implementation.

5. Evaluation

After the Montessori-based teaching aid was introduced in the classroom, students took a post-test with the same set of questions. The results showed a significant improvement, with the average post-test score rising to 94.83 from a pre-test score of 70.34. This sharp increase reflected the positive impact of the teaching aid, helping students to understand and apply addition concepts more easily and with greater confidence.

The effectiveness of the tool was further confirmed by the N-gain test, which showed an improvement of 24.48 points, from 70.34 to 94.83. The N-gain score of 0.78, indicating a 78% improvement, placed the enhancement in students' mathematical abilities within the "high" category. This substantial increase demonstrated the aid's effectiveness in bridging the gap between abstract understanding and practical application, significantly improving students' problem-solving abilities.

The high N-gain score also reinforced that the Montessori-based teaching aid was highly effective in improving students' performance in solving some problems related to the addition concept. By providing concrete, hands-on learning experiences, the aid helped students better grasp abstract concepts, contributing to long-term improvements in their mathematical skills and overall academic performance. These results confirmed that the learning media was a valuable tool in boosting students' achievement in mathematics.

Table 5. Comparison of Pre-test and Post-test Scores with N-Gain Analysis

Pre-test Average	Post-test Average	Difference (Post-Pre)	N-Gain Score	N-Gain Score (%)
70.34	94.83	24.48	0.78	78%

Data Analysis

The analysis involved conducting a normality test using the Kolmogorov-Smirnov test. This statistical test was used to assess whether the distribution of data followed a normal distribution. By applying the Kolmogorov-Smirnov test, we could evaluate the suitability of the data for parametric tests, which often assumed that the data followed a normal distribution. If the test showed that the data significantly deviated from normality, non-parametric methods might be considered for further analysis. This step was crucial to ensure the reliability of subsequent statistical tests and to confirm the assumptions necessary for accurate interpretation of the results.

Table 6. Kolmogorov-Smirnov Normality Test Results for Pre-Test Data

Statistic	Value
Mean	70.34
Standard Deviation	4.42
D (Kolmogorov-Smirnov Statistic)	0.2202
K (Critical Value)	0.2417

The results of the Kolmogorov-Smirnov normality test for the pre-test data were summarized in Table 6. The mean of the pre-test data was 70.34, which represented the average score of the students before the intervention. This suggested that, on average, the students' initial performance was moderately low but not extreme. The standard deviation was 4.42, which indicated a relatively low spread or variation in the pre-test scores, meaning most of the students' scores were clustered around the mean.

The Kolmogorov-Smirnov D statistic, which measured the largest difference between the empirical distribution of the pre-test data and the expected normal distribution, was 0.2202. This value represented the degree of departure from normality. A smaller D value suggested that the data closely followed a normal distribution, while a larger value indicated a more pronounced deviation.

The critical value (K) was 0.2417, which served as a threshold for determining whether the null hypothesis of normality should be rejected. In this case, since the D statistic (0.2202) was smaller than the critical value (0.2417). Therefore, the pre-test data was considered to follow a normal distribution, which allowed for the application of parametric statistical tests.

Based on the results of the Kolmogorov-Smirnov normality test for the pre-test data, we found that the data followed a normal distribution, as the D statistic (0.2202) was smaller than the critical value (0.2417). This suggested that the data was suitable for parametric statistical analyses. Moving forward, the next step was to conduct a similar Kolmogorov-Smirnov normality test on the post-test data. This determined whether the post-test data also followed a normal distribution. If the post-test data was normally distributed, we confidently proceeded with further parametric analyses to assess the effectiveness of the intervention or teaching method used. The results of this test provided valuable insights into whether the assumptions of normality were met, ensuring the validity of subsequent statistical tests on the post-test scores.

Table 7. Kolmogorov-Smirnov Normality Test Results for Post-Test Data

Statistic	Value
Mean	94,83
Standard Deviation	3,11
D (Kolmogorov-Smirnov Statistic)	0,1889
K (Critical Value)	0,2417

The results of the Kolmogorov-Smirnov normality test for the post-test data showed a mean score of 94.83, which reflected a notable improvement compared to the pre-test, suggesting that students' performance enhanced following the intervention. The standard deviation of 3.11 indicateed that the scores were relatively consistent, with most students performing near the average score. This indicated that the majority of students benefited similarly from the intervention, achieving comparable results in the post-test.

The Kolmogorov-Smirnov D statistic for the post-test data was 0.1888, which measured the deviation between the sample distribution and the expected normal distribution. Since this D value was smaller than the critical value of 0.2417, the post-test data was distributed normally. This normality allowed for the use of parametric statistical tests in further analysis, such as a paired t-test, to assess the effectiveness of the intervention in improving students' performance.

The next step in this analysis was to conduct a homogeneity test to ensure that the variances of the data between the groups being tested were homogeneous or uniform. The homogeneity test aimed to verify whether both data groups had the same variance, which was an important assumption in using parametric tests such as the paired t-test. In this study, the researcher used the Bartlett test. This test was chosen based on the number of data being tested, 2 data sets, as well as the results of the Kolmogorov-Smirnov test, which indicated that the pre-test and post-test data were normally distributed (Zhou et al., 2023). If the test results showed that the variances of the two groups were not significantly different, the assumption of homogeneity was met, and further analysis using the paired t-test could proceed to test for significant differences between the pre-test and post-test scores, and evaluate the effectiveness of the intervention.

Table 8. Result of Homogeneity Test Using Bartlett Test

Statistic	Pre-Test	Post-Test
mean	70,34	94,83
1/df	0,034483	0,034483
var	6,125	10,125
ln(var)	1,812379	2,315008
df	1	
B-num	1,812648	
B-den	1,017241	
B	1,781925	
α	0,05	
p-value	0,181913	
B-crit	3,841459	
sig	no	

Based on the results of the Bartlett test, the calculated B value was 1.7819, which was smaller than the B-crit value (3.8415) at the significance level of $\alpha = 0.05$. The obtained p-value was 0.1819, which was greater than 0.05, so the null hypothesis stating that there was no significant variance difference between the pre-test and post-test data was accepted. Therefore, the variances of both groups were considered equal, and a t-test assuming equal variances was used for further analysis.

After conducting the Bartlett test and accepting the null hypothesis that there was no significant variance difference between the pre-test and post-test data, the next step was to proceed with analysis using the paired sample t-test. With variances considered homogeneous, this t-test helped to determine whether there was a significant difference between the means of the pre-test and post-test, providing further insight into the effectiveness of the teaching aid applied in the learning process.

Table 9. T-test Results for Pre-test and Post-test

Statistic	*Post-Test*	*Pre-Test*
Mean	94,83333	70,33667
Variance	29,45402	7,434816
Observations	30	30
Pearson Correlation	0,782678	

Statistic	***Post-Test***	***Pre-Test***
Hypothesized Mean Difference	0	
df	29	
t Stat	36,21761	
P(T<=t) one-tail	5,36E-26	
t Critical one-tail	1,699127	
P(T<=t) two-tail	1,07E-25	
t Critical two-tail	2,04523	

The average score for the pre-test was 70.34, while the average score for the post-test increased to 94.83. This improvement of 24.49 points indicated that the Montessori-based addition teaching aid effectively enhanced the students' arithmetic skills. This reflected the effectiveness of the teaching aid in helping students better grasp the concept of addition.

The variance for the pre-test was 7.43, while the variance for the post-test increased to 29.45. This increase in variance suggested that there was greater variation in students' performance after using the teaching aid. This variation might be due to differences in how students responded to the teaching aid; however, overall, the significant improvement in the post-test scores indicated the success of the intervention.

The correlation between the pre-test and post-test scores was 0.7827, showing a fairly strong relationship. Although the post-test scores were higher, the pre-test results still influenced the final outcome, suggesting that the change in students' skills was related to their initial level of understanding.

The t-test results showed a t-statistic of 36.22, with a very small two-tailed p-value (1.07E-25). This p-value, much smaller than 0.05, confirmed that the difference between the pre-test and post-test scores was statistically significant. This indicated that the improvement in students' skills was not due to chance, but rather the result of using the Montessori-based addition teaching aid.

Overall, the data showede that the Montessori-based addition teaching aid had a significant positive impact on improving students' arithmetic skills. The increase in average scores and the high statistical significance of the t-test results confirmed that this teaching aid effectively facilitated students' development in addition skills. Although the post-test variance was higher, which reflected varying levels of response from students to the aid, the overall results still demonstrated that the tool was effective in enhancing students' understanding and skills in mathematics.

The results of the study, which showed a significant improvement in students' arithmetic skills from the pre-test to the post-test, aligned closely with the idea that the Montessori-based teaching aid fosters a more engaging and interactive learning environment. As the average score increased substantially from 70.34 in the pre-test to 94.83 in the post-test, it was clear that the hands-on, concrete approach of the Montessori method made abstract concepts like addition became more accessible to students.

Previous studies also supported these findings, showing that the use of Montessori-based teaching aids in mathematics education could accelerate students' comprehension. By using tools that allow students to "see" and "experience" mathematical concepts, learning became more meaningful and deeper. This method helped students not only memorize formulas or procedures but also understand the foundation of the concepts being taught, ultimately enhancing their problem-solving abilities in mathematics.

Overall, it could be concluded that the Montessori-based teaching aid has proven to be highly effective in improving students' skills in solving addition problems. This result showed that the Montessori method was a valuable approach to teach mathematics at MI Al-Maarif 02 Singosari, and could serve as a model for other educational institutions seeking to enhance the quality of mathematics instruction. Thus, the use of this teaching aid not only has contributed to improve learning outcomes, but also provide a more enjoyable and profound learning experience for students.

CONCLUSION

Based on the development and testing of the Montessori-based addition teaching aid, the process followed the ADDIE model, which consisted of five stages: Analysis, Design, Development, Implementation, and Evaluation. The teaching aid demonstrated very high acceptability, with scores of 98.6 for the subject matter aspect, 97.3 for the interface, durability, and additional information aspects, and 96 for the pedagogy, presentation, and auxiliary information aspects. In terms of effectiveness, the results revealed a significant improvement in students' arithmetic skills at MI Al-Maarif 02 Singosari, Kabupaten Malang, as evidenced by the substantial increase showed in post-test scores compared to pre-test scores. Specifically, the average score for the pre-test was 70.34, while the post-test average rose to 94.83, reflecting an improvement of 24.49 points. The results of the t-test showed a very high t-statistic of 36.22, with a p-value of 1.07E-25, which was far below the significance level of 0.05, confirming that the improvement in students' arithmetic skills was statistically significant. These findings indicated that the Montessori-based teaching aid effectively enhanced the arithmetic skills of the students at MI Al-Maarif 02 Singosari, Kabupaten Malang.

The contribution of this research to the development of education in Indonesia is significant. It highlights the potential of integrating alternative, student-centered teaching methods like the Montessori approach into formal education, especially in elementary schools. By demonstrating the effectiveness of Montessori-based tools in improving students' understanding of arithmetic concepts, this study opens up new possibilities for innovative teaching strategies in the Indonesian education system. The use of hands-on, experiential learning tools not only helps students engage more actively in the learning process but also offers teachers practical solutions to improve learning outcomes, particularly in foundational subjects like mathematics. This research may encourage more schools across Indonesia to explore and adopt Montessori-based methodologies, leading to a broader transformation in how educational content is delivered and how students interact with their learning environments.

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