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The Effectiveness of the Number Line Board (PAGARI) in Improving the Mathematics Learning Outcomes of Second-Grade Elementary School Students in Multi-Digit Addition and Subtraction

Sabrina Maudy Eka Pratiwi [1*], Kukuh Andri Aka[2], Bagus Amirul Mukmin[3]

[1,2,3]Elementary School Teacher Education, Faculty of Teacher Training and Education, Universitas Nusantara PGRI Kediri
*Corresponding author: sabrinapratiwi29@gmail.com
[2]kukuhandri@unpkediri.ac.id
[3]bagus.am@unpkdr.co.id

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Abstract

Mathematics learning, particularly in multi-digit addition and subtraction, remains a challenge for second-grade elementary school students, as they often have difficulty understanding place value, regrouping, and borrowing techniques. The use of concrete learning media is necessary to help students understand abstract mathematical concepts. This study aims to analyze the effectiveness of the Number Line Board (Papan Garis Bilangan/PAGARI) in improving the mathematics learning outcomes of second-grade elementary school students on multi-digit addition and subtraction. This study employed a Research and Development (R&D) method using the ADDIE model. The research subjects consisted of 8 students in the limited trial and 18 students in the wider trial. Data on effectiveness were obtained from pre-test and post-test results and analyzed using the N-Gain score. The results showed that the students' average learning outcomes in the limited trial increased from 74.38 in the pre-test to 98.75 in the post-test, with an N-Gain score of 0.95, categorized as high. In the wider trial, the average learning outcomes increased from 62.78 in the pre-test to 87.78 in the post-test, with an N-Gain score of 0.67, categorized as moderate. These results indicate that PAGARI is effective in improving the mathematics

learning outcomes of second-grade elementary school students in multi-digit addition and subtraction. The use of PAGARI provides students with concrete and manipulative learning experiences through the integration of a number line, number sticks, question cards, and components for performing multi-digit arithmetic operations, thereby helping students understand arithmetic concepts and procedures in a more meaningful way.

1. INTRODUCTION

Mathematics is one of the essential subjects in elementary education because it plays an important role in developing students' logical, critical, analytical, and systematic thinking skills (Apriza, 2019). Mathematics learning at the elementary school level is not only oriented toward computational skills but also toward conceptual understanding, which serves as a foundation for learning mathematics at subsequent educational levels (Gusmarlia, 2025). However, the abstract nature of mathematical concepts often becomes one of the challenges faced by elementary school students (Siregar & Adinda, 2025), particularly lower-grade students who still require learning experiences involving concrete objects and activities. Therefore, the use of learning media that is appropriate to students' developmental characteristics is necessary to help connect abstract mathematical concepts with real learning experiences (Lubis et al., 2025). Hendriani (2021) explains that the use of concrete media in elementary mathematics learning can help students understand mathematical concepts and support the achievement of learning outcomes, as elementary school students tend to understand concepts more easily when they are presented in concrete or real forms.

According to Ahmad and Mustika (2021), lower-grade elementary school students are still at the concrete operational stage and therefore find it easier to understand concepts through real objects, visual media, and manipulative activities. However, mathematics instruction in schools is still often dominated by lecture-based methods or verbal explanations without the support of concrete learning media (Kurniasari & Maisaroh, 2021). This condition may cause students to focus more on memorizing problem-solving procedures rather than understanding the underlying concepts. Consequently, students experience difficulties in determining place value, applying regrouping techniques in addition, and applying borrowing techniques in multi-digit subtraction (Andriana et al., 2026).

One of the mathematics topics that second-grade elementary school students need to master is multi-digit addition and subtraction (Panggabean et al., 2026). Mastery of this topic serves as a foundation for students to understand various arithmetic operation concepts in subsequent mathematics learning. In the learning

process, students are not only expected to obtain correct answers but also to understand place value concepts and the procedures involved in performing arithmetic operations. Difficulties in understanding place value, regrouping in addition, and borrowing in subtraction may lead students to make errors when solving problems and subsequently result in low mathematics learning outcomes. This condition indicates that learning multi-digit addition and subtraction needs to be supported by learning experiences that enable students to understand the concepts gradually and concretely.

These problems were also identified through observations, interviews with the second-grade teacher, and document analysis conducted at SDN Burengan 1, Kediri City. The data collected indicated that students' learning outcomes in multi-digit addition and subtraction were still suboptimal. In multi-digit addition, 62.5% of students achieved the Learning Objective Achievement Criteria (Kriteria Ketercapaian Tujuan Pembelajaran/ KKTP), whereas in multi-digit subtraction, only 37.5% of students achieved the KKTP, with an average score of 47.5. The teacher interview results also indicated that students still experienced difficulties in understanding place value, regrouping, and borrowing techniques. In addition, learning activities that were still dominated by the use of student worksheets (Lembar Kerja Siswa/LKS) caused some students to lose focus easily and become less active during the learning process. The teacher also stated that concrete learning media were needed to help students understand the material; however, limited time was one of the obstacles to providing and using learning media optimally.

The use of concrete media can be an alternative solution to address these problems. Concrete media enable students to gain learning experiences through objects that can be directly observed and manipulated, making abstract concepts easier to understand. Hendriani's (2021) study showed that the use of concrete media in elementary mathematics learning can support students' learning outcomes and help them understand mathematical concepts through more tangible learning experiences. This finding is further supported by Albaroni, (2021), who reported that the use of concrete media had a positive effect on the mathematics learning outcomes of second-grade elementary school students. The study employed a pre-test and post-test design and demonstrated an increase in the percentage of students achieving learning mastery after the use of concrete media. Thus, concrete media have the potential to serve as learning tools that can help students understand mathematical concepts while improving their learning outcomes.

Various studies have demonstrated that board-based learning media can improve the quality of mathematics learning in elementary schools. Amreta et al. (2023) developed a counting board and reported that the media increased students' average scores from 48.5 to 86.5 after the learning intervention. Similarly, Sembiring & Darwis (2024) found that Daily Number media

received a feasible category based on assessments by experts and teachers and could therefore be used as learning media for addition and subtraction. Meanwhile, Shinta et al. (2024) reported that the implementation of board-based media for multi-digit subtraction increased students' learning mastery from 47% to 79%. Studies by Hafilda et al. (2024) and Hadun et al. (2023) also demonstrated that board-based learning media were effective in improving elementary school students' learning outcomes and numeracy skills.

One type of concrete media that can be used to support learning multi-digit addition and subtraction is the Number Line Board (Papan Garis Bilangan/PAGARI). PAGARI is a manipulative visual learning medium that integrates a board, a number line, pockets for multi-digit arithmetic operations, question cards, and number sticks. The use of this medium provides students with opportunities to engage directly in the learning process through activities involving observation, manipulation, and the completion of arithmetic operations. Through the number line and the available manipulative components, students can gain more concrete learning experiences in understanding number concepts and the processes involved in multi-digit addition and subtraction. Therefore, PAGARI is expected to help students connect mathematical concepts with direct learning experiences, thereby improving their understanding of the material and ultimately contributing to improved learning outcomes.

Several previous studies have demonstrated that the use of concrete and board-based media can contribute positively to mathematics learning in elementary schools. Albaroni (2021) found that concrete media had a positive effect on the mathematics learning outcomes of second-grade elementary school students. In addition, studies on the use of concrete media in mathematics learning have shown that such media can improve the learning process and outcomes by providing students with opportunities to understand concepts through real and manipulable objects. Other studies on concrete media in elementary mathematics learning have also reported improvements in students' understanding and engagement when concrete media are used to explain abstract concepts.

Although numerous studies have investigated the use of concrete media in mathematics learning, research specifically examining the effectiveness of media that integrate a number line with the structure of multi-digit arithmetic operations for second-grade elementary school students remains limited. The media used in previous studies have generally focused on the use of concrete objects or boards as learning aids, whereas PAGARI combines number line visualization, place value concepts, multi-digit arithmetic operations, and manipulative activities within a single learning medium. The integration of these components provides a learning experience that enables students not only to perform calculations but also to understand the concepts and procedures

involved in multi-digit addition and subtraction in a more concrete manner.

Based on these problems and the identified research gap, this study focuses on the effectiveness of the Number Line Board (Papan Garis Bilangan/PAGARI) in improving the mathematics learning outcomes of second-grade elementary school students on multi-digit addition and subtraction. The effectiveness of the media was analyzed based on improvements in students' learning outcomes by comparing pre-test and post-test results, which were subsequently analyzed using the N-Gain score. This study is expected to contribute to the use of concrete and manipulative learning media as an alternative approach to mathematics instruction that is appropriate to the characteristics of elementary school students. Therefore, the objective of this study is to determine the effectiveness of the Number Line Board (PAGARI) in improving the mathematics learning outcomes of second-grade elementary school students on multi-digit addition and subtraction.

2. METHOD

This study employed a Research and Development (R&D) approach using the ADDIE model developed by Branch (2009), which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model was used as a systematic framework for the development and implementation of the Number Line Board (Papan Garis Bilangan/PAGARI) learning media. In this study, the analysis focused on the implementation stage to determine the effectiveness of PAGARI in improving the mathematics learning outcomes of second-grade elementary school students on multi-digit addition and subtraction. The ADDIE model provides systematic stages for the instructional development process, including needs analysis, design, development, implementation, and product evaluation.

The study was conducted at SDN Burengan 1, Kediri City, with second-grade elementary school students as the research subjects. The media was tested in two stages: a limited trial and a wider trial. The limited trial involved 8 second-grade students, while the wider trial involved 18 second-grade students. The limited trial was conducted to obtain an initial overview of the use of the media and to identify students' responses to its implementation, whereas the wider trial was conducted to examine the effectiveness of PAGARI under more representative learning conditions.

Data collection techniques used in this study included observation, interviews, documentation, and learning outcome tests. Observation, interviews, and documentation were conducted during the needs analysis stage to identify problems in mathematics learning and students' difficulties in understanding multi-digit addition and subtraction. The data obtained from observations and interviews served as the basis for developing the PAGARI learning media. Meanwhile, learning outcome tests were used to determine changes in students'

learning outcomes before and after learning with PAGARI.

The primary instrument used to measure the effectiveness of the media was a learning outcome test administered in the form of a pre-test and post-test. The pre-test was administered before students received instruction using PAGARI, while the post-test was administered after students had completed the learning activities using PAGARI. Measuring students' performance before and after instruction enabled the researchers to examine changes in learning outcome scores following the implementation of the media. However, because this study did not include a control group, the observed improvement in learning outcomes was interpreted as a change following the use of PAGARI and was not intended to constitute fully isolated causal evidence independent of other factors. This consideration is important because a one-group pre-test-post-test design has methodological limitations, including the potential effects of maturation, testing effects, and other external factors on changes in learning outcome scores (Marsden & Torgerson, 2012).

The pre-test and post-test data were analyzed quantitatively using N-Gain analysis to determine the level of improvement in students' learning outcomes following instruction using PAGARI. N-Gain analysis was used by comparing the actual increase in students' scores with the maximum possible increase that could still be achieved. Hake (1998) describes normalized gain as a measure of improvement that compares the average actual gain with the maximum possible gain based on the pre-test scores. In this study, the N-Gain analysis results were used as an indicator to describe the level of improvement in students' learning outcomes following the use of PAGARI.

The effectiveness analysis was conducted by comparing the pre-test and post-test results in both the limited and wider trials. The N-Gain score obtained at each trial stage was used to determine the level of improvement in students' learning outcomes. The results of the wider trial served as the primary basis for interpreting the effectiveness of the media because it involved a larger number of students than the limited trial and represented the implementation of the media under broader learning conditions. Subsequently, the N-Gain analysis results were interpreted based on the categories of learning outcome improvement used in this study.

3. RESULTS AND DISCUSSION

Improvement in Students' Learning Outcomes

This study focused on the effectiveness of the Number Line Board (Papan Garis Bilangan/PAGARI) in improving the mathematics learning outcomes of second-grade elementary school students on multi-digit addition and subtraction. The effectiveness of the media was analyzed based on changes in students' learning outcomes before and after instruction using PAGARI through the administration of a pre-

test and post-test. The test results were subsequently analyzed using N-Gain to determine the level of improvement in students' learning outcomes after receiving instruction using PAGARI. The media trial was conducted in two stages: a limited trial involving 8 students and a wider trial involving 18 students. The results of the pre-test, post-test, and N-Gain analyses are presented in Table 1.

Table 1. Pre-Test and Post-Test Result

Trial	Pre-Test	Post-Test	N-Gain	Category
Limited	74.38	98.75	0,95	High
Wider	62.78	87.78	0,67	Moderate

Based on Table 1, an increase in students' average learning outcomes was observed after learning using PAGARI. In the limited trial, the students' average score increased from 74.38 in the pre-test to 98.75 in the post-test. This increase resulted in an N-Gain score of 0.95, which falls into the high category. These results indicate that, at the limited trial stage, the use of PAGARI resulted in a high level of improvement in students' learning outcomes on multi-digit addition and subtraction.

In the wider trial, the students' average score increased from 62.78 in the pre-test to 87.78 in the post-test. The analysis resulted in an N-Gain score of 0.67, which falls into the moderate category. Although the level of improvement in the wider trial was moderate and lower than that observed in the limited trial, the results still indicate an improvement in students' learning outcomes after learning with PAGARI. The wider trial served as the primary basis for interpreting the research findings because it involved a larger number of students and represented the implementation of the media under broader learning conditions.

The findings indicate that PAGARI can be used as an alternative learning medium to help improve the mathematics learning outcomes of second-grade elementary school students in multi-digit addition and subtraction. The improvement in learning outcomes was reflected in the difference between the average scores obtained before and after the use of the media. These findings are also consistent with Milenia (2025), who reported that the use of Papan Susun media in learning short-form written arithmetic operations improved the mathematics learning outcomes of second-grade elementary school students. The study demonstrated that board-based media could help students understand written arithmetic procedures through more concrete learning experiences.

The findings of this study are also consistent with the research conducted by Halim & Fauzi (2025) on the use of Papan Jari media for teaching addition to elementary school students. The study employed a one-group pre-test-post-test design and demonstrated that concrete board-based learning media could help students understand addition concepts that were previously considered abstract. These findings reinforce

the view that learning media that allow students to interact directly with learning objects can support the process of understanding mathematical concepts at the elementary school level.

Effectiveness of the Number Line Board (PAGARI)

The effectiveness of PAGARI in this study was reflected in the improvement in students' learning outcomes after receiving instruction using the media. PAGARI provides a more concrete learning experience through the use of a number line, number sticks, question cards, and components for multi-digit arithmetic operations. Students do not merely receive verbal explanations but also actively participate in learning activities by manipulating the media components to solve addition and subtraction problems.

The use of this media helps students connect mathematical concepts with experiences that can be directly observed. In learning multi-digit addition and subtraction, students need to understand place value as well as regrouping and borrowing procedures. Through the use of PAGARI, these processes can be visualized and carried out step by step, allowing students to understand the relationship between mathematical concepts and calculation procedures. Thus, PAGARI functions not only as a tool for obtaining answers but also as a means of helping students understand the processes involved in solving arithmetic operations.

The findings of this study support the research conducted by Milenia (2025) which demonstrated that the use of Papan Susun media improved the mathematics learning outcomes of second-grade elementary school students in short-form written arithmetic. The similarity between the findings lies in the use of board-based media to help students understand arithmetic operations performed using written procedures. The use of media that can be directly observed and manipulated provides students with a more concrete learning experience, making it easier for them to follow the steps involved in solving arithmetic operations.

The findings are also consistent with the study by Alfina et al. (2026) which implemented Papan Penjumlahan dan Pengurangan media in elementary mathematics learning. The study reported an increase in students' average learning outcomes from 65.7 before the intervention to 75.19 in Cycle I and 85.96 in Cycle II. These findings demonstrate that media specifically designed to help students understand addition and subtraction operations can contribute to improved learning outcomes.

The distinction between PAGARI and the board-based media used in previous studies lies in the integration of several learning components within a single medium. PAGARI combines a number line, multi-digit arithmetic operation components, question cards, and number sticks, allowing students to engage in visual and manipulative learning activities simultaneously. This integration enables students to learn multi-digit addition and subtraction not only through written exercises but also through concrete activities that

actively involve them throughout the learning process.

Discussion of Learning Outcome Improvement in the Limited and Wider Trials

The difference in N-Gain scores between the limited and wider trials indicates that the level of improvement in students' learning outcomes may vary depending on the conditions and characteristics of the learning implementation. The limited trial yielded an N-Gain score of 0.95, categorized as high, whereas the wider trial yielded an N-Gain score of 0.67, categorized as moderate. This difference does not indicate that PAGARI was ineffective in the wider trial but rather reflects differences in the level of improvement in learning outcomes between the two stages of implementation.

In the limited trial, the smaller number of students allowed the learning process to be conducted with more intensive assistance. The teacher was able to provide more targeted attention to each student when using PAGARI. This condition enabled students to understand how to use the media more easily and receive direct guidance when experiencing difficulties. In contrast, the larger number of students in the wider trial resulted in more diverse learning conditions, which may have contributed to differences in the level of improvement in students' learning outcomes.

Nevertheless, the results of the wider trial showed that students' average learning outcomes increased from 62.78 to 87.78, with an N-Gain score of 0.67. This improvement indicates that after using PAGARI, students achieved better learning outcomes than before participating in the learning activities. These findings reinforce the results of Cahyani et al. (2023), which demonstrated that the use of board-based media in mathematics learning can improve students' learning outcomes. The study explained that limited use of learning media and monotonous instruction may contribute to low learning outcomes, whereas the use of board-based media can provide more concrete learning experiences and help students understand the learning material.

The findings of this study also support the research conducted by Azizah et al. (2022) on the use of multiplication board media in elementary mathematics learning. Board-based media can help students interact more actively with mathematical concepts, enabling abstract material to be understood through more concrete experiences. Although the learning material used in that study was different, the principle of using manipulative media is relevant to PAGARI, which provides students with opportunities to engage in direct activities to understand arithmetic operation concepts.

Overall, the findings indicate that PAGARI is effective for teaching multi-digit addition and subtraction in mathematics based on the improvement in students' learning outcomes following the use of the media. This effectiveness was demonstrated by an N-Gain score of 0.95 in the limited trial, categorized as high, and 0.67 in the wider trial, categorized as moderate. These findings suggest that PAGARI can serve as an alternative concrete learning medium to help students understand

the concepts and procedures involved in multi-digit addition and subtraction.

The main strength of PAGARI lies in the integration of number line visualization and manipulative activities in learning multi-digit arithmetic operations. Students have opportunities to see, handle, and directly use the media components throughout the learning process. These experiences can help students connect abstract concepts with concrete representations, making the learning process more meaningful. Therefore, the use of PAGARI not only contributes to improvements in learning outcomes but also provides an alternative approach to mathematics learning that is more concrete and interactive for lower-grade elementary school students.

4. CONCLUSION

It can be concluded that the Number Line Board (Papan Garis Bilangan/PAGARI) is effective as a mathematics learning medium for improving the learning outcomes of second-grade elementary school students on multi-digit addition and subtraction. This is demonstrated by the improvement in students' average learning outcomes after learning using PAGARI. In the limited trial, the students' average score increased from 74.38 in the pre-test to 98.75 in the post-test, with an N-Gain score of 0.95, which falls into the high category. Meanwhile, in the wider trial, the students' average score increased from 62.78 in the pre-test to 87.78 in the post-test, with an N-Gain score of 0.67, which falls into the moderate category.

These results indicate that the use of PAGARI can help students understand multi-digit addition and subtraction through more concrete and manipulative learning experiences. The integration of a number line, number sticks, question cards, and multi-digit arithmetic operation components in PAGARI provides students with opportunities to engage directly in the learning process. Therefore, PAGARI can serve as an alternative concrete and interactive learning medium to support mathematics learning among lower-grade elementary school students, particularly in multi-digit addition and subtraction.

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