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Development of astromath game to enhance interest and understanding in addition and subtraction

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Abstract

Innovative and engaging learning media are needed to overcome elementary school students' low interest and difficulty in understanding basic math operations. Therefore, this study aims to develop and test the validity, practicality, and effectiveness of educational game-based math learning media in understanding basic math calculation operations called Astromath. This media is designed to assist elementary school students in understanding mathematical concepts more enjoyably and interactively. The research employed the Research and Development (R&D) method with the ADDIE development model, which includes the stages of analysis, design, development, implementation, and evaluation. Two material experts validated with a result of 85.83% (very valid category) and two media experts with a result of 90% (very valid category). The practicality test was conducted on two teachers and four first-grade elementary school students. The results of the teachers' assessments showed an average score percentage of 84.37%, categorized as very practical. In comparison, the students' practicality test results obtained an average percentage of 91.1%, which also fell into the very practical category. Furthermore, the pre-test and post-test results demonstrated a significant increase in students' understanding after using Astromath. Therefore, Astromath is declared effective, practical, and suitable for use as an alternative interactive and enjoyable learning media in elementary schools.

Keywords: Astromath, Learning Media, Educational Game

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INTRODUCTION

Education plays an important role in forming a generation that is intelligent, independent, and able to face future challenges. According to (Alam, 2021) education is a very crucial process in developing intelligence, skills, strengthening morals, forming a strong personality, and fostering a spirit of togetherness in order to build themselves independently and contribute to nation building. A central challenge faced by educators today is ensuring that learners not only memorize material, but also understand the concepts underlying each subject. In this case, math, as one of the core subjects, is often a challenge for many learners.

A deep grasp of fundamental principles of mathematics is very important. According to

(Putri. et al., 2024), to successfully reach learning goals in mathematics, students need to build the ability to understand and apply mathematical concepts. This will allow learners to link knowledge between topics and apply it in real life logically. However, various internal factors often lead students to struggle with or lose interest when studying mathematics.

The findings of (Putri, et al., 2024) indicate that students' dislike of mathematics can be caused by lack of interest from the start, difficulty understanding the material, boredom in the learning process, and weak mastery of basic mathematical concepts. This has an impact on the ability of learners to understand the basic concepts of mathematics as a whole. In line with that, the results of the study by (Sando, et al., 2024) showed that although some students had understood the basic concepts of addition and subtraction, they still had difficulty in distinguishing the two operations and had not been able to apply them independently in solving problems. This phenomenon shows the need for a more creative and interactive approach in the mathematics learning process.

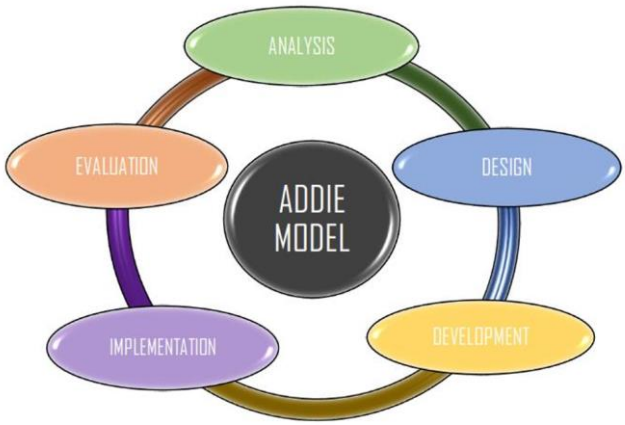
To foster greater interest and deeper understanding of mathematics among students, the commemoration of the International Day of Mathematics managed by UNESCO is one of the important steps. Every year, the International Day of Mathematics organizes various activities that aim to introduce mathematics in a fun way. The theme for the 2025 International Day of Mathematics is Mathematics You Can Touch, which aims to introduce aspects of mathematics that can be felt directly, either through practical experiences or interesting visualizations. Participating in this challenge is important due to its international nature, with more than 5,406 participants from around the world, of which 166 are from Indonesia. One of the largest contributions came from Sriwijaya University, who showed great enthusiasm in celebrating and introducing math in a fun way. One way to introduce math in a fun way is through game-based learning media. Previous research by (Aisah, et al., 2024) showed that teaching media in the form of board games are very effective in improving understanding of mathematical concepts while fostering students' interest in this subject. In line with this, (Annisa, 2024) stated that the use of learning media has been proven to have a positive impact in improving the learning outcomes of students with slow learning speeds. According to (Putri, et al., 2024) game-based learning media has a positive impact by increasing academic achievement and presenting a more meaningful learning experience for students. In addition, (Lestariningsih, et al., 2024) said that snakes and ladders board game media developed with augmented reality technology can effectively support the achievement of learning objectives. Astromath learning media developed by researchers combines the concept of astronauts and mathematics, especially

addition and subtraction operations. The interesting and interactive game concept can be effective for students in understanding basic math calculation operations. The study by (Meitriani, et al., 2023) shows that Game-Based Learning application can boost elementary school students' comprehension of whole number counting concepts and add interactivity and interest to the learning process.

Understanding basic calculations is very important as it is a major foundation in mathematics and everyday life. As stated (Siregar & Dewi, 2022) mathematics emerges as a vital solution and communicative tool in addressing various problems arising from human interactions in fulfilling daily needs, including areas such as trade, business, craftsmanship, and time management, all of which continue to evolve over time. It is proven that learning through games enhances students' understanding of the content, supported by the use of captivating solar system and space-related themes, so as to increase the enthusiasm and enthusiasm for learning of learners during the learning process. However, the research is still limited to the application side. Based on these findings, researchers are interested in developing board game-based teaching media called Astromath, which is media that can be touched directly by learners. Astromath merges basic mathematics ideas with interactive gaming elements inspired by space, aiming to improve students' grasp of math concepts and their motivation, while making the learning process enjoyable and impactful.

METHODS

Using the Research & Development (R&D) framework, this research followed the ADDIE model, encompassing five key phases: Analysis, Design, Development, Implementation, and Evaluation (Octavyanti & Wulandari, 2021). The ADDIE development model is a common and useful model in development research (Nadirah et al., 2024), where the process is carried out sequentially and interactively when used in development research. Because of its perceived thoroughness and rational approach, the ADDIE model can be applied to develop diverse products such as media, teaching aids, models, strategies, and learning techniques (Rohaeni, 2020). The different steps of the ADDIE model are shown in Figure 1.



Source: (Wibawa, Ashrianto, & Pambudi, 2021)

Figure 1. Stages of the ADDIE Model

Researchers begin the process with an analysis stage, involving performance analysis and needs analysis as its two components (Rodiah & U. S, 2023). The first part of the analysis involves assessing students' needs and obstacles in mathematics learning, including identifying what resources are currently missing (Dwitiyanti, et al., 2020), especially in addition and subtraction operations. This study involved four elementary school students as respondents in the analysis stage.

At the next stage, the focus is on designing the media and deciding on the tools and materials to be used. Then, in the development stage, researchers prepare and revise teaching materials by organizing tools and materials, creating media, and modifying existing ones. After development, two experts in media and two content experts validate the teaching aids. The validity of the media was evaluated using a likert scale, and the obtained scores were processed to confirm the product's validity. The number of items along with the ideal scoring range on each evaluation sheet is provided in Table 1.

Table 1. Maximum and Minimum Ideal Scores on Each Rating Sheet

Assessment Sheet	Number of Statement Items	Minimum Score	Maximum Score
Material Expert	12	12	60
Media expert	17	17	85
Teacher assessment	16	16	80
Student assessment	9	9	45

Once the media was declared suitable, the next phase was carried out by testing it among elementary students. The concluding stage consisted of making adjustments to the media based on suggestions from prior stages. The practicality of the product was assessed using evaluation forms completed by teachers and students. The study involved two mathematics teachers and four grade one pupils from an elementary school. Data were gathered on March

26, 2025.

Categories for each evaluation form were established based on the number of statements, the ideal highest score, and the ideal lowest score. The calculation formulas used in the assessments by material experts, media experts, teachers, and students follow the same formulas applied by (Hafiedz & Nurhamidah, 2023). The formula applied is as follows:

$$P(s) = \frac{S}{N} \times 100\% \qquad (1)$$

with
$P\ (s)$: Percentage of sub-indicators
S : Total score for each sub-indicator
N : Total maximum score

Using the formula mentioned above, the standards for validity classification are presented in Table 2 (Rahmawati et al., 2024), while the standards for practicality classification are displayed in Table 3 (Rahmawati et al., 2024).

Table 2. Astromath Validity Categorization Criteria

Score Interval	Validity Category
$80\% \leq Score \leq 100\%$ $80\% \leq Score \leq 100\%$	Very valid
$60\% \leq Score \leq 80\%$ $60\% \leq Score \leq 80\%$	Valid
$40\% \leq Score \leq 60\%$ $40\% \leq Score \leq 60\%$	Valid enough
$20\% \leq Score \leq 40\%$ $20\% \leq Score \leq 40\%$	Less valid
$0\% \leq Score \leq 20\%$ $0\% \leq Score \leq 20\%$	Invalid

Table 3. Astromath Practicality Categorization Criteria

Score Interval	Practicality Category
$80\% \leq Score \leq 100\%$ $80\% \leq Score \leq 100\%$	Very practical
$60\% \leq Score \leq 80\%$ $60\% \leq Score \leq 80\%$	Practical
$40\% \leq Score \leq 60\%$ $40\% \leq Score \leq 60\%$	Practical enough
$20\% \leq Score \leq 40\%$ $20\% \leq Score \leq 40\%$	Less practical
$0\% \leq Score \leq 20\%$ $0\% \leq Score \leq 20\%$	Not practical

The instruments utilized in this research consisted of pre-test and post-test questionnaires, general questionnaires, observations, and interviews. The pre-test and post-test items served to measure the media's effectiveness by comparing student performance prior to and following the use of Astromath. Questionnaires are used to assess the validity and practicality of the developed media. Observation was conducted to observe learners' activities during the trial process, including their level of participation and interaction with the learning media. Data collected from the four instruments were analyzed to assess how effective and high-quality the learning media is in facilitating the teaching of addition and subtraction operations.

RESULTS AND DISCUSSIONS

A. Analysis Stage

Analysis is conducted in two stages, which are performance analysis and needs assessment. The performance analysis stage is carried out to determine whether the learning process at school is as expected or requires improvement of the learning program (Insani, et al., 2023). Findings from the analysis reveal that learners face challenges in comprehending and recalling addition and subtraction concepts. This corresponds with research (Wahyuni & Suyoto, 2024) which shows that there are various difficulties faced by students, including difficulties in performing addition and subtraction operations, lack of mastery of addition and subtraction procedures, and not fully mastering addition and subtraction calculation operations. Unvaried learning resources make students lose interest in learning. The following step is the needs analysis stage, which focuses on identifying performance issues to find appropriate solutions.

At the needs analysis stage, the researcher also determined solutions to increase learner interest. The observation results showed that traditional learning is often less interesting and can feel boring for students. Therefore, more interactive media is needed to actively involve students in the learning process. Astromath was chosen as a solution because it is an educational game that combines the concept of astronauts and mathematics, especially addition and subtraction operations. The game is designed to train counting skills in a fun and interactive way. Players will take on the role of an astronaut exploring the game board and must complete math challenges to continue the journey. With an interesting and interactive concept, Astromath can be effective for students in understanding basic math calculation operations. In improving students' understanding of elementary school math lessons, interesting and entertaining media is needed as a tool to facilitate learning (Wabula et al., 2022).

B. Design Stage

During this stage, the development of Astromath learning media takes the form of a specially designed educational game to assist students in learning mathematics, especially in addition and subtraction operations. This instructional media is based on the rules of the snakes and ladders game and developed from the design by (Lutfiana, et al. 2024). The designer chose a space theme to attract learners' interest, this is characterized by the use of elements such as rockets, planets, meteors, and aliens. The game design includes a game path from the "Start" to "Finish" point, with boxes containing addition and subtraction problems that the player must solve. Each path comes with additional instructions such as "Go two steps forward" and meteor

and alien symbols to add dynamics to the game. The game also comes with dice and rocket-shaped pawns that can be moved with ropes. Figure 2 shows the design of Astromath.

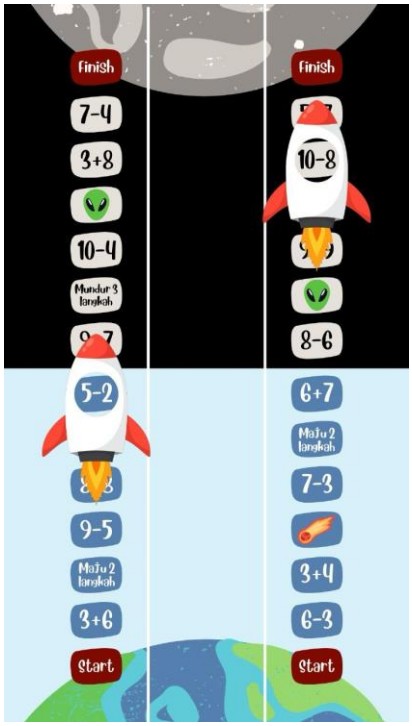


Figure 2. Astromath design

The creator includes a sheet containing instructions for playing Astromath along with a scannable QR code to access the answer sheets for the questions. Figure 3 shows the design of the game guide and Figure 4 shows the design of the answer key.

Figure 3. Astromath Guide Design

Figure 4. Answer Key QR Code

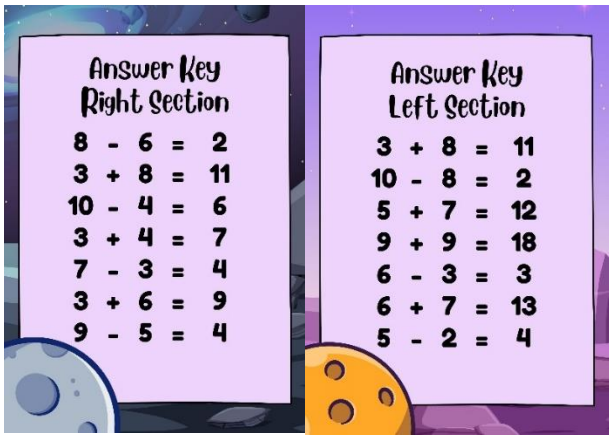


Figure 5. Astromath Answer Key Design

After the digital design was completed, the researchers commenced the production of Astromath learning media utilizing multiple tools, namely; scissors, brushes, markers, pens, and rulers. As for the materials used, namely; cardboard, cardboard paper, paper glue, solation, double tape, acrylic paint, nylon rope, and printed paper.

1. Manufacturing Steps

a. Prepare the tools and materials, then start making designs for the Astromath learning media, such as rockets and media names to be printed.
b. Then cut a small cardboard paper measuring 3 cm × 2 cm, for game questions, the remaining cardboard is cut long with a width of approximately 1.5 cm and then folded to a thickness of 0.5 cm to be attached to the question cardboard that has been made so that the question looks higher than the base.
c. Then make questions on the pieces of paper with a marker.
d. After that, paint pictures of the earth and moon using acrylic paint to enhance the media to match the theme of astronauts and math.
e. Next, cut the design of the media name and rocket that has been printed as needed. The rocket is covered with thick paper to make it sturdy.
f. Next, cut a 40 cm × 22 cm piece of cardboard for the base of the Astromath media.

g. Then, line the cardboard base with cardboard paper attached using paper glue.
h. Once the base is complete, start to combine the elements that have been made previously by taping them together using double-sided tape.
i. When everything is done, add nylon ropes on both sides of the problem to place the rocket so that the rocket can be pulled.
j. The last step is to make dice from paper by cutting paper in the shape of a cube net with sides of 2 cm × 2 cm, after forming a cube net, color the paper with color markers and give the eyes of the dice, then put the paper together to form a cube.
k. Astromath learning media is ready to use.

2. Development Stage

During this stage, the development of Astromath media will proceed according to the prepared design, covering the design stage, revision stage, manufacturing stage, and concluding with the final stage to create the product.

3. Peer Validation

During the manufacturing stage, the 80% completed product was then validated with peers. During the peer validation process, there were several suggestions and comments, namely: a. The base is given the name of the game; b. The rocket is strengthened again; c. The rocket rope is added on each side; d. Change the game rules; e. Add game time; f. The dice are filled so that they are not too light. Once peer review was completed, the development and modification of the Astromath learning media were initiated by the researchers.

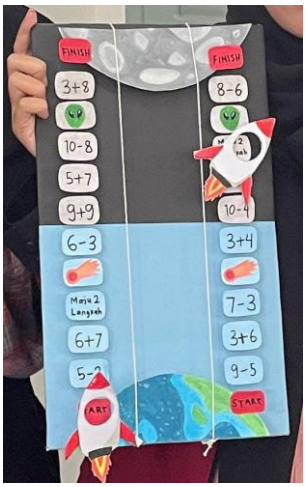


Figure 6. Astromath Media Before Revision

Figure 7. Astromath Media After Revision

4. Validity and practicality test of astromath learning media

At this stage, the quality of the Astromath learning media is assessed by two material experts and two media experts through a learning media exhibition held in celebration of Pi-Day, officially recognized as the International Day of Mathematics (IDM), by the Doctoral Program of Mathematics Education at Sriwijaya University. The results of the evaluation by material and media experts regarding the media's validity are presented in Table 4 and Table 5.

Table 4. Astromath Learning Media Validity Test Results by Material Experts

Validity Assessor	Total Score
Material Expert 1	47
Material Expert 2	54
Average Score	50,5
Percentage of Average Score	84,16%
Validity Category	Very Valid

Table 5. Results of Astromath Learning Media Validity Test by Media Experts

Validity Assessor	Total Score
Media Expert 1	79
Media Expert 2	83
Average Score	81
Percentage of Average Score	90%
Validity Category	Very Valid

Based on Table 5 and Table 6, it can be concluded that Astromath learning media is suitable for use. However, there are some suggestions given. During the revision stage, several enhancements were carried out based on validation feedback, including the addition of a barcode linking to fundamental material that students are expected to review prior to using the learning media.

Final validation of the Astromath instructional tool yielded strong results, with 85.83% approval from content experts and 90% from media professionals, indicating that the media met quality benchmarks. After revising the tool, researchers moved on to measure its practicality through real-world testing.

The practicality test involved two math teachers and four students. Teachers rated the media using a form containing 16 items based on a five-point Likert scale. For Astromath to qualify as practical, it had to achieve an average score of at least 60%. Table 6 provides the assessment data.

Table 6. Results of Astromath Learning Media Practicality Test by Teachers

Practicality Assessment	Total Score
Teacher 1	67
Teacher 2	68
Average Score	67,5
Percentage of Average Score	84,37%
Practicality Category	Very Practical

In addition, the practicality evaluation by students was carried out using a questionnaire consisting of 9 statements, assessed with a five-point Likert scale. To be classified as practical by students, Astromath must obtain an average score of at least 60%. The teacher evaluation results related to the practicality of Astromath are outlined in Table 7.

Table 7. Results of Astromath Learning Media Practicality Test by Students

Practicality Assessment	Total Score
Student 1	42
Student 2	43
Student 3	40
Student 4	39
Average Score	41
Percentage of Average Score	91,1%
Practicality Category	Very Practical

C. Implementation Stage

Astromath learning media was tested directly with four students from one of the Palembang State Elementary Schools on March 26, 2025. The objective of conducting this trial was to find out whether Astromath can stimulate students' enthusiasm for learning, is simple to operate, and contributes to a pleasant learning process. In addition, this trial aims to assess the effectiveness of Astromath in helping students understand addition and subtraction material that was previously considered difficult to understand through conventional learning.

Figure 8. Documentation of Trial with Learners

D. Evaluation Stage

This stage of evaluation was intended to measure the impact of Astromath educational media on students' learning performance.. This evaluation includes aspects of learners' involvement while using the media, the extent to which the media helps them understand the material, as well as general responses to the visual appearance and game mechanism. Evaluation data was collected through interviews and direct observation of learners after the pilot test. The evaluation results show that Astromath is able to increase learners' active participation and help them understand the concept of addition and subtraction better through a fun and interactive approach.

Following interviews conducted with four elementary school students who participated in the Astromath learning media trial, the following information was obtained:

1. The concept understanding video given at the beginning helped them to re-understand the material that had previously been taught at school, making it easier for them to play Astromath.
2. Astromath has an attractive appearance, so students feel interested to try and use it.
3. The rules of the Astromath game are easy to understand, so learners do not experience difficulties when playing.
4. Astromath provides a fun learning experience, especially in understanding addition and subtraction, as it combines learning concepts with fun games.
5. Astromath increases students' motivation to be more enthusiastic in mastering addition and subtraction materials.
6. Astromath helps learners in understanding and mastering the material, because the questions that appear in the game encourage them to think and recall the material that has been learned.

Based on the observations made during the trial of Astromath learning media, some important information was obtained as follows:

1. Learners who have watched the video at the beginning can understand and remember the concepts of addition and subtraction.
2. Learners can very easily understand how to play Astromath, without the need for repeated explanations or intensive help.
3. Learners show understanding of the questions that appear in the game, and appear motivated to answer the questions correctly in order to win the game.

The interviews and observations on the use of Astromath learning media indicate that

this tool positively influences students' learning processes, particularly in grasping addition and subtraction concepts. Feedback from four elementary students in the trial revealed that Astromath boosts enthusiasm for learning and strengthens material mastery. Students were attracted by the engaging visuals and simple game rules. This game-based media offers a unique learning experience by presenting challenges that stimulate active thinking and participation. This aligns with prior research showing that game-based learning fosters students' enthusiasm and motivation in math, addressing the issue of low interest caused by monotonous teaching methods.

This finding aligns with the studies conducted by (Putri et al., 2024) and (Lestariningsih et al., 2024), which highlight that game-based learning media can effectively enhance students' motivation and engagement in mathematics. In contrast to the traditional Snakes and Ladders Math game, which features relatively simple visuals and gameplay mechanics, Astromath provides a more modern and dynamic learning experience. The learning process begins with an engaging conceptual video, followed by a board game activity designed with distinctive and interactive visuals. This combination of concept delivery and visual challenges encourages students to participate more actively, stay focused, and demonstrate greater enthusiasm throughout the learning session. The difference in approach has a notable impact on students' level of engagement and their understanding of mathematical concepts. The structure and content of Astromath were found to be aligned with curriculum objectives, indicating strong content validity based on expert and user feedback. Nevertheless, implementing Astromath also presents certain challenges, particularly in ensuring that adequate devices are available to support smooth media access and video display. Despite this, Astromath is intentionally designed for student-driven use, requiring minimal teacher guidance, as clear instructions and answer keys are provided from the outset. This autonomy serves as a distinct advantage, enabling students to explore and learn independently. Even so, occasional supervision or light facilitation remains beneficial to keep the learning process aligned with instructional goals.

Astromath uses an engaging and enjoyable method, making it effective at fostering a vibrant and captivating learning environment. During the activity, learners showed high enthusiasm, both for the visual appearance of the media and the ease of following the game flow. Astromath not only made the learning process more fun, but also motivated students to answer the questions more seriously. An active and interactive learning atmosphere is successfully realized through this learning media, So that learners can comprehend the content

more effectively without compromising the fundamental meaning of the lesson. The successful integration of Astromath into the learning process is influenced by several key factors, including the availability of devices to support video playback and media operation, as well as students' digital competence in navigating the tool independently. In addition, learners' preferences for visually engaging and challenge-based activities significantly contribute to the overall effectiveness of this media. These three elements collectively shape the extent to which Astromath can deliver an enjoyable and meaningful learning experience that enhances students' conceptual understanding.This approach clearly helps overcome their difficulties in understanding and remembering concepts, as well as reviving interest in learning that had declined in the conventional learning process.

Through pre-test and post-test administrations, cognitive skills were assessed to evaluate Astromath learning media's impact on learners' grasping and retaining addition and subtraction concepts. The pre-test was administered before using Astromath media to establish students' baseline understanding and identify difficulties. Subsequently, the post-test was conducted following the learning sessions to assess the progress made through the media.

A comparison between pre-test and post-test outcomes is presented in Table 8, illustrating how Astromath contributes to resolving learners' comprehension and retention issues regarding addition and subtraction.

Table 8. Students' pre-test and post-test results

No.	Code Name	Pre-test score	Post-test score	Value Increase
1.	H	60	100	40
2.	D	60	100	40
3.	W	80	100	20
4.	P	80	100	20

The analysis of learners' pre-test and post-test scores revealed that every student showed improvement after engaging with the Astromath learning media. This result indicates that the media plays a beneficial role in assisting students to overcome challenges in grasping and recalling addition and subtraction concepts. This finding aligns with earlier studies that highlight the effectiveness of augmented reality-based snakes and ladders board games in supporting learning goal attainment. The increase in scores reflects the effectiveness of Astromath in overcoming students' difficulties in understanding and remembering the concepts of addition and subtraction through a fun and interactive learning approach. Thus, it can be concluded that the use of Astromath is able to support the achievement of learning objectives more optimally.

CONCLUSION

From the results and discussion, it is concluded that the Astromath educational game-based learning media designed to enhance elementary students' understanding of addition and subtraction operations has been proven both valid and practical. This media was developed using the ADDIE model within the Research and Development framework, involving stages of analysis, design, development, implementation, and evaluation, which effectively produced high-quality learning media. Validation scores were excellent, with 85.83% from material experts and 90% from media experts, while teacher and student practicality assessments yielded 84.37% and 91.1%, respectively. Astromath proved to be an alternative learning media that is interactive and fun, and able to overcome students' difficulties in understanding basic mathematical concepts, where the integration of pedagogical elements and digital interactivity based on a constructivist approach allows students to learn through direct experience actively. This study was conducted using non-probability sampling, so further research needs to be developed involving subjects from various schools and more diverse levels of education in order to obtain more representative results. This study contributes to the development of game-based learning tools for elementary education and opens up opportunities for future research, including more extensive trials, expansion of content to other areas of mathematics, and integration with online learning platforms.

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