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Interactive Digital Manipulatives Using Wordwall to Enhance Elementary Students' Interest and Learning Outcomes in Addition and Subtraction

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Abstract: This study aims to develop Wordwall-based interactive digital media to enhance second-grade students' interest and learning outcomes in addition and subtraction. Mathematics learning in elementary schools faces challenges, including low student interest and poor learning outcomes due to limited variation in teaching methods and media. This research employs the Research and Development (R&D) method using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) with 28 second-grade students as the subjects. Data collection techniques include observation, interviews, questionnaires, and tests. The developed media presents addition and subtraction through engaging educational games designed for students in the concrete operational stage, featuring virtual manipulatives that simulate hands-on learning experiences. Validation results show high media quality with expert ratings of 92% (material validity) and 88% (media validity). Learning interest increased significantly, with 89% of students responding positively to the interactive features. Learning outcomes improved substantially, with pre-test scores averaging 65.4, increasing to post-test scores of 84.2, and classical learning completeness rising from 57% to 89%. Statistical analysis (paired t-test, $p < 0.05$) confirms a significant improvement. This research demonstrates that Wordwall-based digital manipulatives effectively enhance both interest and achievement in elementary mathematics, contributing to the quality of education in the digital era.

Keyword: Digital manipulative media; Learning interest; Learning outcomes; Wordwall

Introduction

Mathematics is a fundamental subject in elementary education that equips students with logical, analytical, and critical thinking skills. According to Suhendri (Suhendri, 2011), mathematics is a discipline that discusses numbers, forms, relationships between concepts, and logical principles, which are studied through symbols or notation in an effort to solve everyday problems. In addition to being an exact science, mathematics also contains educational values that play a role in shaping student character and training logical and systematic thinking abilities in facing life's challenges (Ningrum et al., 2015). According to the Ministry of Education and Culture in Novitasari et al. (2018), the objectives of mathematics learning are to develop thinking abilities, solve problems, improve learning outcomes, train the delivery of ideas, and form positive character. However, in practice, achieving these goals still faces various challenges, such as low learning interest, lack of contextual learning approaches, and limited supporting facilities (Elfiyani, 2024). The success of mathematics learning in elementary schools highly depends on the teacher's role in designing appropriate, effective, and student-characteristic-based learning (Silvia et al., 2024). Although mathematics learning plays an important role in developing logical and analytical thinking abilities, its implementation still

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faces various challenges, including students' negative perceptions that consider it difficult and boring (Kholil et al., 2020). This negative perception makes students less interested and even afraid to learn, resulting in less effective learning. To overcome this, appropriate and innovative strategies are needed that can increase student interest and confidence (Intan et al., 2022).

Good arithmetic skills, particularly in addition and subtraction, are the main foundation for mastering more complex mathematical concepts. Mastery of these skills is not only needed in academic contexts but is also essential in daily life. In real life, arithmetic skills can be applied in various activities, such as preparing personal financial budgets, calculating expenses and income, determining discounts when shopping, and making decisions based on numerical data. Despite mathematics having a very important role, many students show low interest in this subject, which is reflected in unsatisfactory learning outcomes in arithmetic materials. Research conducted across various elementary schools in Indonesia consistently shows that students consider mathematics a difficult subject. One persistent problem at the elementary school level is low mathematics learning outcomes, particularly in basic arithmetic operations (Putri et al., 2022).

Preliminary observations conducted at MIN 2 Madiun City revealed specific challenges in second-grade mathematics learning. Based on interviews with the mathematics teacher and classroom observations in November 2024, it was found that 64% of second-grade students (18 out of 28 students) scored below the minimum completeness criteria (KKM) of 75 in addition and subtraction materials during the mid-semester assessment. Students demonstrated low engagement during mathematics lessons, with only 35% actively participating in class discussions. The teacher reported that students frequently complained about difficulty understanding abstract numerical concepts and showed limited enthusiasm during conventional teaching methods. These findings indicate an urgent need for innovative learning media that can bridge the gap between abstract mathematical concepts and students' concrete operational thinking stage.

The use of attractive learning media appropriate to student characteristics can be a solution to overcome this problem, thus arousing student learning interest, especially in mathematics subjects at the elementary school level. The use of media in the learning process can arouse student interest and motivation, reduce or avoid verbalism, stimulate orderly and systematic reasoning, and develop understanding and values in students (Muliyadi et al., 2023; Munandar et al., 2024; Prayudi et al., 2022). According to Batubara (2020), students aged 7-8 years (typically in second grade) are in Piaget's concrete operational stage, where children are capable of logical reasoning about real situations or objects but do not yet have the ability to think abstractly. At this stage, students benefit significantly from learning experiences that provide concrete representations of abstract concepts, making the use of manipulative media crucial for effective mathematics instruction (Nurhayati et al., 2023).

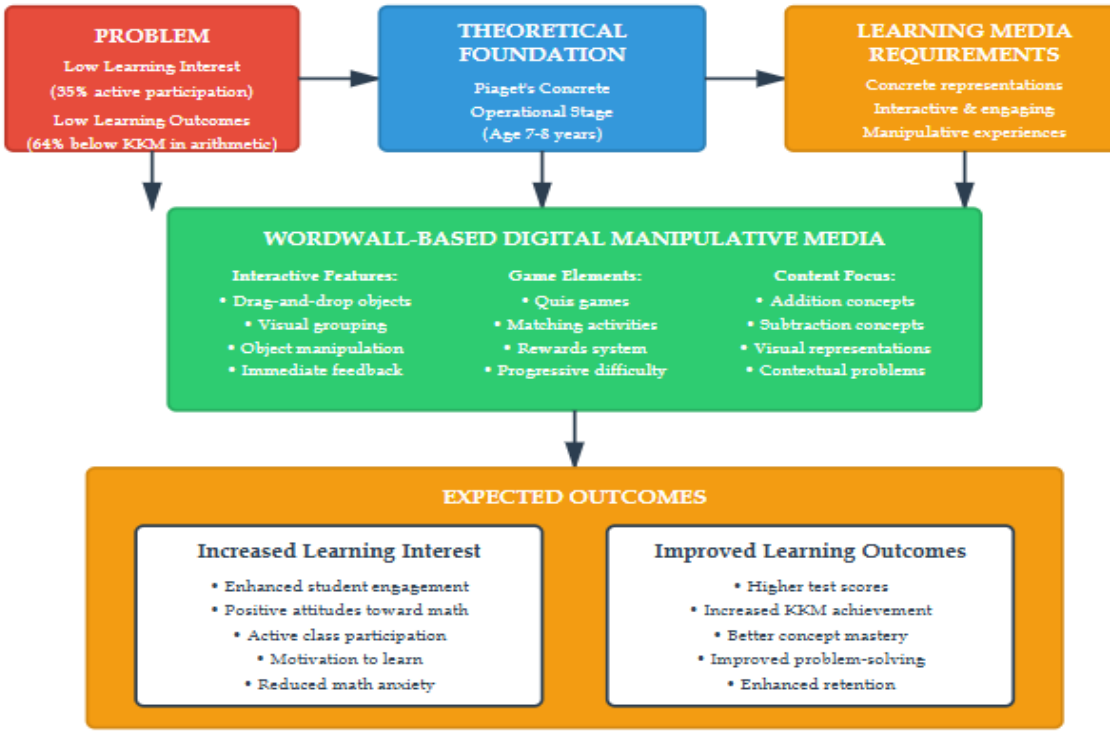

Figure 1. Conceptual framework flowchart

One promising solution is developing Wordwall-based interactive digital manipulative learning media. Digital manipulatives are virtual representations of physical objects that students can manipulate on screen to explore mathematical concepts, bridging the gap between concrete and abstract thinking. Wordwall application is a web-based learning platform that can be effectively utilized to create interactive, game-style learning activities. Unlike traditional quiz platforms, Wordwall offers features that can simulate manipulative experiences through visual object manipulation, drag-and-drop interactions, and immediate feedback mechanisms. These features are particularly suitable for teaching addition and subtraction concepts, as they allow students to virtually group, combine, and separate objects—mirroring the cognitive processes involved in these operations (Prayudi et al., 2022). This media offers various customizable features such as interactive games, quizzes, and matching activities that can increase student engagement while maintaining focus on mathematical concept development.

This research aims to develop Wordwall-based interactive digital manipulative media that can increase student learning interest and outcomes in addition and subtraction materials for second grade at MIN 2 Madiun City. The novelty of this research lies in several key aspects: (1) the integration of digital manipulative media concepts with the Wordwall interactive platform specifically designed for elementary mathematics, addressing the gap in literature where most Wordwall applications focus on language learning or general quizzes rather than mathematical manipulatives; (2) specific focus on addition and subtraction materials for second-grade students, considering their concrete operational cognitive stage with empirically tested design features; (3) comprehensive evaluation of both learning interest and learning outcomes as dependent variables, providing holistic evidence of media effectiveness; and (4) contextualized implementation in Indonesian Islamic elementary schools (Madrasah Ibtidaiyah), contributing to the limited research on technology integration in religious-based elementary education settings.

This research is important for several reasons. First, it addresses the persistent achievement gap in elementary mathematics by providing an evidence-based technological solution aligned with cognitive development theory. Second, it contributes to achieving Sustainable Development Goal 4 (Quality Education) by promoting inclusive and equitable quality education through innovative, accessible digital learning tools. Third, in the context of Indonesia's digital education transformation, this research provides practical guidance for teachers and curriculum developers on effectively integrating affordable web-based platforms into mathematics instruction. Finally, the research expands the theoretical understanding of how digital manipulatives can be designed and implemented to support early elementary mathematics learning in developing country contexts.

Method

This research employs the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to develop Wordwall-based interactive digital manipulative media for second-grade addition and subtraction instruction. The ADDIE model was selected for its systematic and clearly structured stages, enabling researchers to design, develop, and validate learning media effectively (Branch, 2009). The research framework is illustrated in Figure 1.

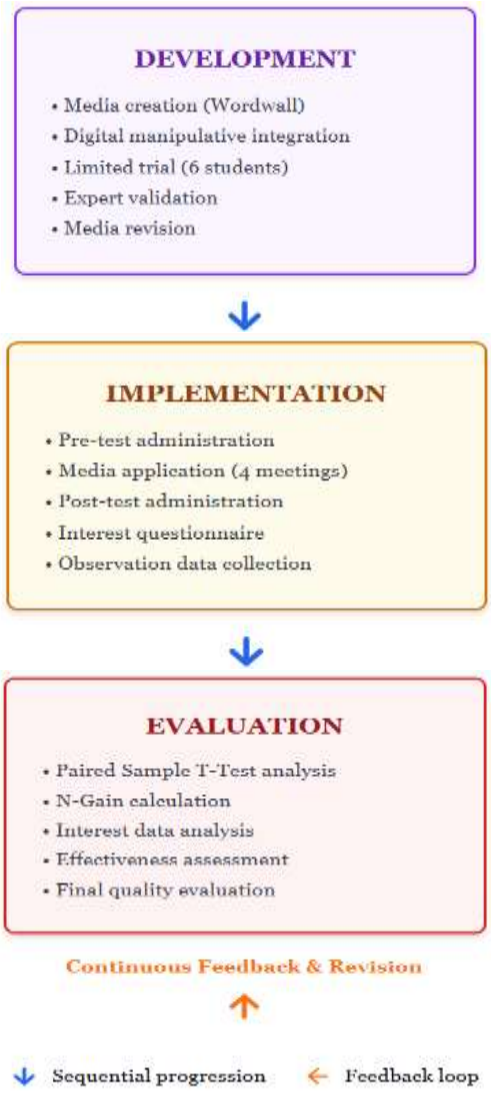

Figure 2. ADDIE model research framework research setting and subjects

The research was conducted at MIN 2 Madiun City, East Java, Indonesia, from January to June 2025. The research subjects consisted of 28 second-grade students (14 male, 14 female) aged 7-8 years. All subjects were enrolled in the 2024/2025 academic year and had studied addition and subtraction material according to the standard curriculum.

The detailed research stages based on the ADDIE model are presented in Table 1.

Table 1. Research Stages Based on ADDIE Model

Stage	Activities	Expected outcomes	Instruments
Analysis	Needs analysis through teacher interviews and classroom observations; curriculum analysis of K-13 mathematics standards; identification of second-grade students' cognitive characteristics aligned with concrete operational stage; analysis of existing learning media limitations	Description of instructional needs, relevant basic competencies (KD 3.3 and 4.3), and student learning challenges in addition and subtraction	Teacher interview guide; classroom observation sheet; curriculum document analysis form
Design	Designing Wordwall-based interactive media architecture; determining digital manipulative types (drag-and-drop grouping, visual counting, matching activities); designing storyboard, navigation flow, and user interface; developing prototype mock-ups for expert review	Initial design blueprints, storyboard with interaction flows, and media prototype specifications	Media design template; storyboard document; expert validation instrument draft
Development	Creating interactive media using Wordwall platform features; integrating digital manipulative elements (visual representations of objects for addition/subtraction operations); conducting limited trial with 6 students outside research subjects; expert validation by material and media experts; media revision based on validation feedback	Beta version of Wordwall-based interactive digital manipulative media validated as feasible; revised media ready for implementation	Material expert validation sheet; media expert validation sheet; limited trial observation notes; media revision checklist
Implementation	Applying validated media in actual learning process over 4 meetings (2 weeks); conducting pre-test before media implementation; conducting post-test after media implementation; collecting student interest data through questionnaires; observing student engagement during media usage	Media used by 28 second-grade students in authentic learning contexts; quantitative data on learning outcomes; qualitative data on student responses	One Group Pretest-Posttest design; media usage observation sheet; learning interest questionnaire; learning outcome test (pre-test and post-test)

To evaluate media effectiveness, this research employed a One Group Pretest-Posttest Design (Sugiyono, 2019). This quasi-experimental design measures the effect of the treatment (Wordwall-based media implementation) by comparing learning outcomes before and after intervention within a single group. The design notation is: O_1 X O_2.

Where: O_1 = Pre-test (initial measurement of learning outcomes before media implementation). X = Treatment (implementation of Wordwall-based interactive digital manipulative media). O_2 = Post-test (final measurement of learning outcomes after media implementation)

The same group of 28 second-grade students received the pre-test, participated in four learning sessions using the developed media, and then completed the post-test. This design was selected due to practical constraints in establishing a control group within the school setting and the exploratory nature of R&D research focused on product development and initial effectiveness testing.

During the Development stage, a limited trial was conducted with 6 second-grade students from a parallel class (not included in the 28 main research subjects) at MIN 2 Madiun City. The trial objectives were: (1) testing media readability and navigability; (2) identifying technical issues or confusing interface elements; (3) conducting preliminary reliability testing of learning outcome instruments; and (4) gathering initial student feedback for media refinement. The trial lasted two sessions (90 minutes total) and resulted in minor revisions to button placement, instruction clarity, and game difficulty levels before expert validation.

Material Expert Validation Sheet: Assesses content accuracy, curriculum alignment, material completeness, clarity of examples, and appropriateness for second-grade cognitive level. Uses a 5-point Likert scale.

Media Expert Validation Sheet: Evaluates visual design quality, interface usability, navigation ease, interactivity effectiveness, and technical functionality. Uses a 5-point Likert scale.

Learning Interest Questionnaire

A 20-item questionnaire adapted from Keller's ARCS model (Attention, Relevance, Confidence, Satisfaction) measures student learning interest after media implementation. Items use a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Example items include: "I enjoy learning addition and subtraction using Wordwall games" and "The digital media helps me understand mathematics concepts better."

A 20-item multiple-choice test covering addition and subtraction competencies (single-digit and two-digit operations, word problems) aligned with KD 3.3 and 4.3. Each correct answer scores 5 points (maximum score: 100). The test serves as both pre-test and post-test with identical items to measure learning gain.

A structured observation checklist was used to document student engagement, participation patterns, technical difficulties, and teacher–student interactions during media implementation across four learning sessions.

Content Validity: All instruments (validation sheets, interest questionnaire, learning outcome test) underwent content validation by two expert validators (one mathematics education expert, one educational technology expert) to ensure construct appropriateness and content coverage. Validators assessed each item's relevance and clarity, resulting in revisions to 3 questionnaire items and 2 test items before finalization.

Empirical Validity: The learning outcome test was piloted with 30 third-grade students at a different school (SDN 1 Madiun) to conduct item analysis. Item validity was calculated using Product Moment Correlation (Pearson r), with validity criteria $r > 0.361$ ($\alpha = 0.05$, $n = 30$). Results showed 18 of 20 items were valid; 2 items were revised and retested until achieving acceptable validity coefficients.

Interest Questionnaire: Cronbach's Alpha reliability coefficient was calculated using pilot data from 30 students. The questionnaire achieved $\alpha = 0.89$, indicating high internal consistency reliability ($\alpha > 0.70$).

Learning Outcome Test: Test reliability was assessed using Kuder-Richardson Formula 20 (KR-20) for dichotomous items. The test achieved KR-20 = 0.84, indicating high reliability ($r > 0.70$).

Qualitative data from teacher interviews, student feedback, and observation notes were analyzed using Miles et al. (1994) interactive model consisting of three stages:

Data Reduction: Selecting, focusing, and simplifying raw data from interview transcripts and observation notes to identify relevant themes related to media usability, student engagement, and instructional challenges.

Data Display: Organizing reduced data into structured formats (matrices, narrative summaries) to identify patterns in student responses and teacher perceptions regarding media effectiveness.

Conclusion Drawing/Verification: Interpreting patterns to draw conclusions about media strengths, weaknesses, and areas for improvement, verified through triangulation with quantitative findings. Expert validation scores were calculated using the formula:

$$P = (\Sigma x / \Sigma x\_i) \times 100\% \quad (1)$$

Where: P = Feasibility percentage; Σx = Total score obtained from validators; Σx_i = Maximum total score.

Table 2. Feasibility Interpretation Criteria (Akbar, 2013)

Percentage Range	Category
81.00 - 100.00	Very feasible
61.00 - 80.00	Feasible
41.00 - 60.00	Fairly feasible
21.00 - 40.00	Less feasible
0.00 - 20.00	Not feasible

Student interest questionnaire data were analyzed using descriptive statistics (mean, percentage) with interpretation criteria:

Table 3. Student Interest Criteria

Score Range	Category
4.21 - 5.00	Very high
3.41 - 4.20	High
2.61 - 3.40	Moderate
1.81 - 2.60	Low
1.00 - 1.80	Very low

Paired Sample T-Test: To determine whether the difference between pre-test and post-test scores is statistically significant ($\alpha = 0.05$). Prerequisites: normality test using Shapiro-Wilk test. N-Gain Analysis: To measure the effectiveness level of learning improvement using the formula:

$$\text{N} - \text{Gain} = \frac{(\text{Post-test Score} - \text{Pre-test Score})}{(\text{Maximum Score} - \text{Pre-test Score})} \quad (2)$$

Table 4. N-Gain Interpretation Criteria (Hake, 1999)

N-Gain Range	Effectiveness Category
0.70 - 1.00	High
0.30 - 0.69	Moderate
0.00 - 0.29	Low

Classical Learning Completeness: Percentage of students achieving minimum completeness criteria (KKM = 75), calculated as:

$$\text{Classical Completeness} = \frac{\text{Number of Students} \geq \text{KKM}}{\text{Total Students}} x\ 100\% \quad (3)$$

Learning is considered classically complete if ≥ 85% of students achieve KKM. All quantitative analyses were conducted using SPSS version 26.0 software.

Table 5. Validation Assessment Criteria and Scoring Rubric

Validated aspect	Score interpretation
Relevance to learning objectives	5.00 = Very relevant; 4.00 = Relevant; 3.00 = Fairly relevant; 2.00 = Less relevant; 1.00 = Not relevant
Curriculum suitability	5.00 = Very suitable; 4.00 = Suitable; 3.00 = Fairly suitable; 2.00 = Less suitable; 1.00 = Not suitable
Media feature diversity	5.00 = Very diverse; 4.00 = Diverse; 3.00 = Fairly diverse; 2.00 = Less diverse; 1.00 = Not diverse
Student involvement in media	5.00 = Very high; 4.00 = High; 3.00 = Moderate; 2.00 = Low; 1.00 = Very low
Visual design quality	5.00 = Very high quality; 4.00 = High quality; 3.00 = Moderate quality; 2.00 = Low quality; 1.00 = Very low quality
Satisfaction with interactivity	5.00 = Very satisfying; 4.00 = Satisfying; 3.00 = Fairly satisfying; 2.00 = Less satisfying; 1.00 = Not satisfying
Ease of use	5.00 = Very easy; 4.00 = Easy; 3.00 = Fairly easy; 2.00 = Difficult; 1.00 = Very difficult
Effectiveness in improving learning outcomes	5.00 = Very effective; 4.00 = Effective; 3.00 = Fairly effective; 2.00 = Less effective; 1.00 = Not effective

Table 6. Overall Validation Feasibility Categories

Average score range	Feasibility category
4.21 - 5.00	Very feasible
3.41 - 4.20	Feasible
2.61 - 3.40	Fairly feasible
1.81 - 2.60	Less feasible
1.00 - 1.80	Not feasible

Results and Discussion

Based on the needs analysis conducted at MIN 2 Madiun City, several findings were identified. The target students studied are second-grade students at MIN 2 Madiun City who are in the concrete operational cognitive development stage. The material to be developed is addition and subtraction. Learning needs include increasing student interest in mathematics, improving learning outcomes through more interactive media, and facilitating independent and collaborative learning.

Problems faced include students being less interested in mathematics materials due to a lack of attractive media, learning media used currently still tending to be conventional, and students having difficulty understanding basic concepts of addition and subtraction. Learning objectives are for students to understand basic concepts of addition and subtraction, for students to solve addition and subtraction problems correctly through digital manipulative media, and to increase student involvement and learning motivation.

Media Design

The developed media is Wordwall-based interactive digital manipulative media in the form of games, quizzes, and practice questions with attractive visual forms. The media design structure is illustrated in Figure 3.

Interactive features include drag-and-drop where students can drag numbers to arrange addition and subtraction problems, image selection where students choose images that match the addition/subtraction results, a timer providing time challenges to increase student thinking speed, and direct feedback where after students' complete problems, the system provides immediate feedback regarding correct or incorrect answers. The interactive feature specifications are presented in Table 7.

Figure 3. Wordwall-based interactive digital manipulative media design structure

The learning structure consists of an introduction with brief explanation of addition and subtraction materials, core activities where students do various interactive games such as simple addition games and subtraction games with visual images, and closing with learning outcome review and feedback provision.

Table 7. Wordwall Media Interactive Feature Specifications

Feature	Description	Learning Objectives
Drag-and-drop	Students drag numbers to arrange addition and subtraction problems	Training understanding of number concepts and arithmetic operations
Image selection	Students choose images matching calculation results	Connecting abstract concepts with visual representations
Timer	Time challenge to complete problems	Increasing thinking speed and accuracy
Direct feedback	Immediate system response on answer correctness	Providing instant reinforcement and correction
Leaderboard	Display of scores and rankings	Increasing motivation through healthy competition

Development and Implementation Results

The developed media prototype uses Wordwall to create various types of interactive games according to the material. Addition games require students to choose the correct number to complete addition problems. Subtraction games require students to arrange subtraction problems by choosing appropriate images or numbers. Quizzes provide multiple-choice questions to measure student understanding.

Based on pretest and posttest data, student learning outcomes showed significant improvement after using Wordwall-based interactive digital manipulative media. The comparison of pretest and posttest scores is presented in Table 8.

Table 8. Comparison of Student Pretest and Posttest Scores

Name	Pretest	Posttest	Improvement
Adiba	71	96	25
Alvirsya	60	87	27
Alwi	69	100	31
Andhara	69	89	20
Aqueenzha	58	91	33
Assyifa	80	100	20
Hwang	73	96	23
Ibrahim	71	96	25
Khalifa	30	85	55
Mahameru	58	93	35
Malika	69	100	31
Mila	69	100	31
Muhammad Ahsan	30	87	57
Muhammad Fattah	71	100	29
Muhammad Naufal	73	100	27
Mutiara Kirana	58	89	31
Narendra Zakir	70	100	30
Nayla Syifa	73	100	27
Nazifa Azkanida	30	89	59
Nizam Dzaki	30	87	57
Pradika Ahsan Putra	30	85	55
Pramudhita Aghni	73	100	27
Qaira Almaira	73	100	27
Raffasya Asyer	30	89	59
Raya Nafisha	30	87	57
Rezvan Nizama	30	89	59
Shaka Ali Salman	73	100	27
Shakila Aleena	69	100	31
Average	57.32	94.07	36.75

Based on Table 4, there was a significant increase in student learning outcomes with an average pretest score of 57.32 increasing to 94.07 on the posttest, with an average improvement of 36.75 points. The distribution of pretest and posttest scores is illustrated in Figure 4.

Figure 4. Distribution of student pretest and posttest scores

The data shows that all students experienced improvement in learning outcomes after using Wordwall-based interactive digital manipulative media. Students with initially low pretest scores (30) showed the most significant improvement, with increases

reaching 55-59 points. This indicates that the developed media is effective in helping students who initially had difficulty understanding addition and subtraction materials.

Discussion

The research results support previous findings showing that Wordwall use can increase student learning motivation, seen from increased participation, courage to ask questions, and enthusiasm during the learning process (Azzahra et al., 2024; Fatkhullah et al., 2025; Putri et al., 2022). Students claimed to understand materials more easily and to be more actively involved in the learning process. This shows that Wordwall can rekindle the interest and participation of students who were previously less enthusiastic and passive.

Compared to conventional methods without media, using Wordwall is proven to be more effective in creating a fun and interactive learning atmosphere. Additionally, this platform is easy to use, affordable, and provides various template choices that allow teachers to present materials more creatively. With this engaging approach, students tend to be more focused and motivated to learn (Hidayat et al., 2025; Sabiila, 2024). The summary of media effectiveness analysis results is presented in Table 9.

Table 9. Summary of Wordwall-Based Interactive Digital Manipulative Media Effectiveness

Aspect	Indicator	Result	Category
Learning Outcomes	Average pretest score	57.32	Low
	Average posttest score	94.07	Very High
	Average improvement	36.75	Significant
	Students reaching KKM (≥75) on pretest	10 students (35.7%)	Low
	Students reaching KKM (≥75) on posttest	28 students (100%)	Very High
Learning Interest	Student enthusiasm	High	Positive
	Active participation	High	Positive
	Willingness to repeat activities	High	Positive

The novelty of this research lies in developing Wordwall-based interactive digital manipulative media specifically for addition and subtraction materials in second grade at MIN 2 Madiun City. This research not only measures the effectiveness of Wordwall use but also develops the media itself by adapting content, appearance, and game mechanisms according to the cognitive characteristics of second-grade students.

Conclusion

This research successfully developed Wordwall-based interactive digital manipulative media for second-grade addition and subtraction instruction through systematic ADDIE model stages (Analysis, Design, Development, Implementation, Evaluation). Expert validation demonstrates high media feasibility, with material expert validation achieving 4.60/5.00 (92%, Very Feasible category) and media expert validation reaching 4.40/5.00 (88%, Very Feasible category). The media effectively enhances student learning interest, with questionnaire results averaging 4.45/5.00 (89%, High category), indicating strong student engagement and positive attitudes toward mathematics learning. Learning outcomes improved substantially, with pre-test mean scores of 57.32 increasing to post-test mean scores of 94.07, representing a 36.75-point gain. Classical learning completeness rose dramatically from 35.7% (10 of 28 students) to 100% (28 of 28 students achieving KKM ≥ 75). N-Gain analysis yielded 0.72 (High effectiveness category), and Paired Sample T-Test results ($t = 15.84$, $df = 27$, $p < 0.001$) confirm statistically significant improvement. These findings demonstrate that Wordwall-based digital manipulatives effectively bridge concrete and abstract mathematical thinking for second-grade students in the concrete operational stage, providing accessible and engaging instructional solutions that align with contemporary digital learning environments.

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data collection, manuscript writing, and editing, integrating supervisory guidance to achieve optimal results. Gratitude is extended to PGRI Madiun University for institutional support throughout the research process. The authors also thank family members for their moral support and motivation. Finally, the authors acknowledge that this research has limitations and hope these findings contribute to mathematics education development in elementary schools, particularly in integrating digital technology to enhance student learning outcomes.

Author Contributions

Conceptualization, W.M. and L.N.P; methodology, C.P.P, validation, expert team (not specified by initials); formal analysis, A.R; investigation, R.D.P resourses MIN 2 Madiun City and PGRI Madiun University; data curation A.R. writing original draft preparation, R.D.P; writing – review and editing, W.M and L.N.P visualization, technical support team; supervision, W.M and L.N.P all authors have read and greed to the publish version of the manuscript.

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Conflicts of Interest

No conflicts of interest were declared by the author.

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