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INTERACTIVE DIGITAL MATH MEDIA FOR ENHANCING ELEMENTARY STUDENTS' LEARNING OUTCOMES

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Abstract
This study aims to develop an interactive learning media called Digital Math Learning and test its validity, practicality, and effectiveness in improving elementary school students' mathematics learning outcomes. This study is based on students' low understanding of mathematical concepts influenced by the limited variety of learning media used by teachers, so that the learning process tends to be monotonous and lacks active student participation. The study used the Research and Development (R&D) method with the ADDIE model which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The research subjects included experts, teachers, and students. Data were collected through observation, questionnaires, tests, interviews, and documentation, and analyzed using the validity, practicality, and effectiveness of the learning media. The results showed that the developed interactive learning media, Digital Math Learning, met the criteria for validity, practicality, and effectiveness. Expert validation in terms of content, media, and language produced an overall score categorized as very valid, indicating that the media is feasible for instructional use. Practicality testing also showed a very practical category, as teachers and students found the media easy to use, engaging, and relevant to elementary learners' needs. In terms of effectiveness, the learning outcomes demonstrated a significant improvement, with an N-Gain score of 0.80 (high category) and a student response rate of 96.08% (very effective category). Digital Math Learning effectively enhances conceptual understanding and student engagement and has the potential to become an interactive and adaptive digital learning solution aligned with learning styles and cognitive abilities.
Keywords: *math learning; interactive learning media; learning outcomes*

Abstrak
Penelitian ini bertujuan untuk mengembangkan media pembelajaran interaktif *Digital Math Learning* serta menguji tingkat validitas, kepraktisan, dan efektivitasnya dalam meningkatkan hasil belajar matematika siswa sekolah dasar. Penelitian ini didasarkan pada rendahnya pemahaman konsep matematika siswa yang dipengaruhi oleh terbatasnya variasi media pembelajaran yang digunakan guru, sehingga proses pembelajaran cenderung monoton dan kurang melibatkan partisipasi aktif peserta didik. Penelitian menggunakan metode *Research and Development* (R&D) dengan model ADDIE yang meliputi tahap *Analysis, Design, Development, Implementation,* dan *Evaluation*. Subjek penelitian meliputi ahli, guru, dan siswa. Data dikumpulkan melalui observasi, angket, tes, wawancara, serta dokumentasi, dan dianalisis menggunakan validitas, kepraktisan, serta efektivitas media pembelajaran. Hasil penelitian menunjukkan bahwa media pembelajaran interaktif Digital Math Learning memenuhi kriteria valid, praktis, dan efektif. Hasil validasi oleh ahli materi, media, dan bahasa memperoleh skor rata-rata dengan kategori *sangat valid*, sehingga layak digunakan dalam proses pembelajaran. Uji praktikalitas menunjukkan kategori *sangat praktis*, karena guru dan siswa menilai media ini mudah digunakan, menarik, dan sesuai dengan kebutuhan belajar siswa sekolah dasar. Dari aspek efektivitas, hasil belajar siswa mengalami peningkatan yang signifikan dengan nilai N-Gain sebesar 0,80 (kategori tinggi) dan respon siswa sebesar 96,08% (kategori sangat efektif). Digital Math Learning efektif meningkatkan pemahaman konsep dan keterlibatan siswa, serta berpotensi menjadi solusi pembelajaran digital interaktif dan adaptif yang sesuai dengan gaya belajar serta kemampuan kognitif.
Kata Kunci: math learning; media pembelajaran interaktif; hasil belajar

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Introduction

In today's digital era, education has undergone a fundamental transformation, with technology becoming an integral component of students' daily learning experiences and a key driver of quality improvement in Indonesian schools (Lovandri Dwanda Putra & Suci Zhinta Ananda Pratama, 2023). According to Isti'ana (2024), technology integration supports interactive learning, broadens access to information, and enhances learning outcomes. Similarly, Apriani et al. (2024) emphasize that educational technology serves as a foundation for improving learning effectiveness in modern classrooms.

However, while technology offers great potential, its successful implementation depends on appropriate pedagogical design and teacher readiness (Kusnadi, 2024). In mathematics learning, this balance between technological innovation and pedagogy is crucial. Mathematics is not merely about numbers, it fosters logical reasoning, problem-solving, and analytical thinking skills essential for lifelong learning (Mailani et al., 2022). The *Kurikulum Merdeka* underscores the importance of numeracy development across domains such as algebra, measurement, geometry, statistics, and problem-solving (Purwandari et al., 2024).

To ensure these goals are met, mathematics learning should employ interactive and contextual approaches supported by technology. Interactive learning media can visualize abstract mathematical concepts, promote student engagement, and facilitate deeper understanding (Rio Ferdinan Nababan et al., 2024). For example, geometric principles that are difficult to grasp through traditional explanations can be illustrated through animations and simulations (Pradana, 2025). Likewise, adaptive digital platforms offering real-time feedback encourage students to learn at their own pace while maintaining motivation.

Nonetheless, research also reveals that implementing interactive learning media presents several practical challenges. Teachers often face limited digital literacy, time constraints in developing materials, and inadequate infrastructure (Mulyani et al., 2023; Sari & Kurniawan, 2024). Additionally, many schools still rely on passive digital tools, such as PowerPoint presentations or static videos that do not engage students actively or provide adaptive feedback (Hatmoko et al., 2024). These constraints hinder the realization of technology's full potential in improving mathematical understanding.

This challenge is particularly evident in the context of Bukittinggi City, where digital classrooms are gradually being introduced to enhance mathematics learning quality. Initial observations show that while teachers acknowledge the benefits of digital tools, their application remains limited to conventional uses, resulting in low engagement and motivation among students. Common difficulties include poor comprehension of abstract materials like fractions and geometry, and the inability to apply concepts independently.

Teachers also report a shortage of interactive digital media that align with students' learning needs. Existing materials often lack animation, gamification, or formative feedback mechanisms that adjust to students' varying learning speeds. Meanwhile, students demonstrate high enthusiasm for game-based and animation-supported learning, which they perceive as more enjoyable and aligned with their learning styles.

To bridge this gap between potential and practice, it is essential to design innovative and adaptive learning tools. Interactive media such as Digital Math Learning exemplify this approach by combining pedagogical design with technological features including visualization, simulation, and gamification (Verdiatmoko & Pinandita, 2025). The platform provides learning videos, digital worksheets, educational games, and adaptive quizzes, all supported by automated feedback and cross-device accessibility. These features not only promote independent learning but also create a more engaging and meaningful classroom experience.

The development of *Digital Math Learning* responds directly to the identified needs in Bukittinggi's elementary schools. By integrating technology, pedagogy, and content holistically, this initiative supports teachers in delivering material more effectively and equitably. At the same time, it enhances students' motivation, comprehension, and problem-solving abilities—marking a crucial step toward realizing the full potential of digital mathematics education in Indonesia.

Research Methods

This research was conducted using the research and development (R&D) method. Sugiyono, (2015) states that R&D is a research method used to produce a specific product and test its effectiveness (Rachma et al., 2023). In this study, the resulting product is an interactive learning media using Digital Math Learning, which is expected to improve student learning outcomes. The development procedure in this R&D research uses the ADDIE model. According to Rachma et al., (2023) there are 5 stages in this model, namely; Analyze, Design, Develop, Implement and Evaluate.

Analyze Stage. The analysis stage in this study aims to identify the need for learning media development and assess the product's feasibility. In this study, the researcher analyzed several important aspects, namely literature, curriculum, student needs, and student characteristics.

Design Stage. The design stage in the ADDIE model aims to design learning strategies that are effective, interesting, and appropriate to students' needs. The steps taken in the design stage for developing the Digital Math Learning application include: (a) Preparation of the Learning Media Framework, (b) Determining the Systematic Material, (c) Selection of the Media and Technology Used, (d) Designing the User Interface, and (e) Determining the Learning Evaluation.

Development Stage. The Development stage is a crucial phase in which the learning plan developed during the design stage is transformed into a tangible product ready for testing and use. This stage aims to produce and verify learning resources to ensure they meet student needs and characteristics. The processes undertaken during this development stage include: (a) Creating Learning Media, (b) Validation by Experts and Focus Group Discussions, (c) Individual Trials, (d) Small Group Trials, and (e) Revisions.

Implementation Stage. The implementation phase aims to apply the developed learning media to a real-life learning context to determine the product's functionality, effectiveness, and suitability to user characteristics. The implementation phase involved all students in the elementary school digital classroom as trial subjects. The validated, practical, and effective Digital Math Learning media was implemented in the learning process. Students completed a questionnaire on material clarity, usability, appearance, and relevance, followed by a posttest to assess conceptual understanding, ensuring the media's suitability for enhancing mathematics learning in elementary digital classrooms.

Evaluation Stage. The evaluation phase consists of formative and summative evaluations. Formative evaluation is conducted at each ADDIE stage through expert validation, individual trials, and small group testing to refine the product according to learning needs. The summative evaluation at the final stage assesses the overall validity, practicality, and effectiveness of the Digital Math Learning media, ensuring it is suitable, engaging, user-friendly, and able to enhance elementary students' mathematics learning outcomes in digital classrooms.

The subjects in this study consisted of experts serving as media validators, as well as teachers and students as direct users during the implementation and evaluation stages. Subject selection was conducted purposively for the teacher and expert groups, taking into account their competencies and the relevance of their expertise to the development of learning media. Meanwhile, for the student group, cluster random sampling or total sampling techniques were used to ensure the representativeness and validity of the data obtained. The main subjects of the study were fourth-grade elementary school students participating in digital classes at SDN 01 Benteng Pasar Atas and SDN 03 Pakan Kurai in Bukittinggi City, with a total of 49 students involved in the large-scale implementation or field trial stage. In the previous stages, the study also involved six students in small-group trials, several teachers and educational practitioners in individual trials, and 20 participants consisting of supervisors, principals, digital class teachers, and postgraduate students in a Focus Group Discussion (FGD). This approach was intended to obtain comprehensive input from various stakeholders, ensuring that the research results possess high validity and relevance to the context of elementary school learning.

Data collection in this study was adjusted to the stages of development, implementation, and evaluation based on the ADDIE model. To obtain comprehensive and valid data, several data collection methods were employed, including observation, questionnaires, learning achievement tests, interviews, and documentation. The use of multiple techniques was intended to support data triangulation and enhance the validity of the research findings. The main instruments included expert validation sheets used by media and material experts to assess the quality, feasibility, and accuracy of the developed digital learning media. In addition, teacher and student response questionnaires were utilized to evaluate aspects of practicality, ease of use, and the level of engagement during classroom implementation.

This study uses a quantitative and qualitative approach in analyzing data obtained from the development and trial process of interactive learning media Digital Math Learning on the material of measurement units in elementary school digital classes.

Data Analysis of the Validity of Digital Math Learning Media. Validity analysis assessed content, presentation, and usability of Digital Math Learning media using expert evaluations via a 5-point Likert questionnaire.

Table 1. Learning Media Validity Assessment Score

Interval	Category
5	Strongly agree
4	Agree
3	Neutral
2	Disagree Less
1	Don't agree

The validity value of each validator is calculated using the formula:

$$NP = R/SM \times 100\%$$

Information:

NP = Value percentage sought
R = Score acquisition
SM = Score maximum

The validity values are then classified into the following categories:

Table 2. Interpretation of Validation Results

Interval (%)	Validity Category
0%-20%	Invalid
21%-40%	Less valid
41%-60%	Quite valid
61%-80%	Valid
81%-100%	Very valid

Practicality Analysis. Practicality analysis assessed ease of use, efficiency, and acceptability of Digital Math Learning media via teacher and student questionnaires.

Table 3. Teacher and Student Questionnaire Assessment Scale

Interval	Category
5	Strongly agree
4	Agree
3	Neutral
2	Disagree Less
1	Don't agree

The validity value of each validator is calculated using the formula:

$$NP = R/SM \times 100\%$$

Information:

NP = Valuepercentage sought

R =Score acquisition

SM = Scoremaximum

The practicality level category of the interactive learning media Digital Math Learning used in this study can be seen in Table 4 below:

Table 4. Interpretation of Practical Results

Score	Interpretation
0%-20%	Not practical, can't be used
21%-40%	Less practical, can't be used
41%-60%	Quite practical, can be used but needs major revision
61%-80%	Practical, can be used but needs minor revisions
81%-100%	Very practical, can be used without revision

Effectiveness Analysis

Learning outcome test. Effectiveness of Digital Math Learning media was measured using pretests and posttests, with N-gain analysis assessing improvements in students' conceptual understanding.

N-Gain = (Posttest Score-Pretest Score)/(Maximum Score-Pretest Score)

Information:

Posttest score =final test scores

Pretest score =initial test scores

Maximum score = ideal maximum score (100)

To determine the level of improvement in student learning outcomes, the Normalized Gain (N-Gain) value is used. This value is analyzed based on the following criteria:

Table 5. Interpretation of N-Gain

N-Gain	Criteria
N-Gain> 0.7	Tall
0.3 ≤ N-Gain < 0.7	Currently
N-Gain< 0.3	Low

Learning media is considered appropriate for use when the majority of students demonstrate at least moderate improvement, with effectiveness evaluated according to the established classification table.

Table 6. Effectiveness Interval Categories

N-Gain Percentage Interval	Effectiveness Criteria
N-Gain Percentage < 40%	Ineffective
40% ≤ N-Gain Percentage < 55%	Less Effective
56% ≤ N-Gain Percentage ≤ 75%	Quite Effective
N-Gain Percentage < 76%	Effective

Effectiveness Questionnaire (Student Response Questionnaire). To measure the level of effectiveness based on student questionnaires, the following formula is used:

$$Ve = (\sum X / \sum Y) \times 100\%$$

Information:

Ve = Percentage of media effectiveness level

∑X = Total actual scores obtained from all questionnaire items

∑Y = Maximum possible score obtained

The percentage values obtained from the above calculations are then classified into effectiveness categories based on the following table:

Table 7. Effectiveness Interval Categories

Interval (%)	Effectiveness Category
0%–20%	Ineffective, not suitable for use
21%–40%	Less effective, not suitable for use
41%–60%	Quite effective, usable but needs major revision
61%–80%	Effective, worth using with minor revisions
81%–100%	Very effective, can be used without revision

Referring to the classification above, Wegos-based learning media is considered effective if it achieves a minimum score in the "quite effective" category, meaning it has a minimum effectiveness percentage of 41%. A percentage below that indicates the media is unsuitable for use in the learning process without comprehensive improvements.

Result and Discussion

This study developed Digital Math Learning media via a Microsite, integrating videos, e-books, interactive games, worksheets, and assessments for digital-class students.

Analysis Stage

At this stage, feasibility, needs, and criteria for designing effective learning media are analyzed, including student needs assessment, curriculum analysis, and examination of relevant digital learning media characteristics. In terms of the curriculum, the transition from the 2013 Curriculum to the Independent Curriculum provides more flexibility in designing media based on teaching modules, learning outcomes (CP), and learning objectives (TP), and encourages the

integration of digital technology in mathematics learning. Analysis of the characteristics of fourth-grade students at SDN 01 Benteng Pasar Atas and SDN 03 Pakan Kurai shows that they have a high interest in using interactive digital media, but still experience obstacles in understanding the concepts of fractions and geometric shapes. In this study, the selected material focused on the topic of Flat Shapes because it is closely related to everyday life, is cognitively challenging, and supports the achievement of critical thinking competencies, problem-solving, and student creativity through contextual interactive learning experiences.

Design Stage

At this stage, the initial design of Digital Math Learning media is compiled using flowcharts and storyboards to ensure a systematic, comprehensible, and engaging learning experience for students. Digital Math Learning media is developed using a Microsite as the main platform for presenting interactive learning content with an attractive appearance, easy navigation, and multimedia features. Supporting applications such as YouTube, Book Creator, Canva, Educaplay, Zepquiz, and Quizizz are used to enrich the media content through videos, e-books, quizzes, games, and interactive assessments. This media is designed to allow students to learn independently and flexibly with a page structure, visual elements, and fun practice questions that strengthen mathematical understanding.

Figure 1. Initial View

Figure 2. Instructions for Use

Figure 3. Learning Outcomes

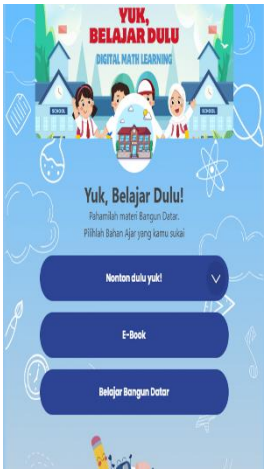

Figure 4. Learning Features

Development Stage

In the development phase, the design is realized into a tangible product, with validity, practicality, and effectiveness assessments ensuring its appropriateness and alignment with learning objectives.

Instrument validity. In this study, instruments included questionnaires and test items supporting learning media validation, such as material and media design validation, teacher and student practicality, student media response, and test questions measuring students' mathematical critical thinking skills across individual, small-group, and effectiveness trials.

Table 8. Research Instrument Validation Results

Aspect	Number of Grains	Total Score (R)	Maximum Score (SM)	NP (%)	Category
Content	10	49	50	98.00%	Very Valid
Construct	10	49	50	98.00%	Very Valid
Language	10	50	50	100.00%	Very Valid

Validation results indicated content and construct scored 98%, and language 100%, confirming the instrument is relevant, consistent, clear, and suitable for use without major revisions.

Material Validation. Validation emphasized curriculum alignment, material accuracy, completeness, contextual relevance, and the integration and logical sequence of content presentation.

Table 9. Results of Material Expert Validation

No	Questionnaire	Amount scores obtained	Amount maximum score	Percentage	Category
1.	Subject matter expert validation	69	75	92%	Very Valid

Material expert validation yielded a score of 69/75 (92%), categorizing Digital Math Learning media as "Very Valid," indicating high-quality content, alignment with learning outcomes, completeness, and presentation, suitable for elementary mathematics digital classrooms.

Design Validation. Design assessment considered functional suitability, usability for elementary students, digital performance, classroom reliability, content quality, device compatibility, and ease of updating and transferring.

Table 10. Expert Design Validation Results

No	Questionnaire	Amount scores obtained	Amount maximum score	Percentage	Category
1.	Design expert validation	84	90	93.33%	Very Valid

Design expert validation of Digital Math Learning media resulted in a score of 84/90 (93.33%), categorized as "Very Valid," indicating excellent design quality, usability, digital performance, reliability, content quality, device compatibility, and ease of updating, making it highly suitable for elementary students in digital learning environments.

Language Validation. Linguistic assessment, conducted via a closed questionnaire, evaluated indicators including readability, communicativeness, developmental appropriateness, relevance to digital mathematics, grammar, terminology suitability, and language difficulty aligned with elementary students' cognitive characteristics.

Table 11. Results of Validation by Linguists

No	Questionnaire	Amount scores obtained	Amount maximum score	Percentage	Category
1.	Linguist validation	91	100	91%	Very Valid

Validation by language experts scored Digital Math Learning media 91/100 (91%), categorized as "Very Valid," indicating the language meets high-quality standards. It demonstrates readability, communicativeness, developmental appropriateness, alignment with digital mathematics learning, correct grammar and effective sentence structure, suitable terminology, and language difficulty appropriate to elementary students' cognitive abilities.

Focus Group Discussion (FGD). A Focus Group Discussion (FGD) was conducted with 20 participants, consisting of supervising lecturers, supervisors, principals, digital classroom teachers, and postgraduate students. The discussion highlighted the advantages of Digital Math Learning media, which was considered interesting and increased student learning interest. However, several suggestions were made. The digital classroom teacher suggested adding user instructions on the home page, the school supervisor emphasized the alignment between Learning Objectives (TP) and Learning Outcomes (CP), while other participants highlighted the need for functional differentiation between menus, such as games, LKPD, and assessments.

Figure 5. Focus Group Discussion (FGD)

Individual Trial. Individual trials in this study were conducted to gather direct input from education practitioners, especially teachers, regarding the interactive learning media Digital Math Learning that had been developed.

Table 12. Individual Trial Results

No	Questionnaire	Amount the score that obtained	Total score maximum	Percentage	Category
1.	Individual trials	100	110	90.91%	Very Practical

Individual trials of Digital Math Learning media yielded a score of 100/110 (90.91%), categorized as "Very Practical." Teachers positively responded to the interactive design and systematic presentation, concluding the media is highly practical for teaching, enhancing student engagement, and improving understanding of mathematical concepts, particularly plane figures.

Small Group Trial. After completing the individual trial phase, the research continued with a small group trial phase. This phase aims to measure students' direct responses and reactions to the developed interactive Digital Math Learning media. This small group trial involved two digital class students, selected based on varying levels of academic ability: two students with high ability, two students with medium ability, and two students with low ability. This selection aims to ensure that the evaluation results better represent the diversity of student characteristics in the digital class.

Based on the results of research completed by 6 students who have used learning media in the mathematics learning process (data attached in the attachment). Each statement in the questionnaire was assessed using a 5-point Likert scale, with a score range of 1 (Strongly Disagree) to 5 (Strongly Agree). The maximum score of all statements was 510 (17 statements × 6 students × maximum score of 5), and the score obtained from the results of filling out the questionnaire by students was 429. So the practicality percentage value of 84.12% is in the "Very Practical" category. This means that the Digital Math Learning media is considered to be easy and enjoyable to use by students in learning activities. Almost all indicators received high scores, especially in aspects of comfort of use, ease of access, interactivity, and enjoyable learning activities.

Implementation Stage

The implementation phase evaluated the effectiveness of Digital Math Learning media through a large-scale field trial involving 49 fourth-grade students from SDN 01 Benteng Pasar Atas and SDN 03 Pakan Kurai. Learning activities were carried out offline through two meetings, with a pretest at the initial meeting to measure students' initial abilities related to the material on flat shapes and a pretest after the learning process was carried out. The learning employed a blended approach combining face-to-face instruction and digital technology, integrating game-based elements. Pretest and posttest analyses assessed the effectiveness of the Digital Math Learning media.

Table 13. Summary Results of the Effectiveness Test of Using Canva Learning Media

No	Pretest Average	Posttest Average	Average N-Gain Score	Category	Average N-Gain Score (%)	Category
1	45.91	89.28	0.80	Tall	80.87	Effective

Based on the results of pretest and posttest data processing from 49 students, the average N-Gain value was 0.8087, or 80.87% as a percentage (data attached in the attachment). This

value is in the high category, indicating that learning using the developed media can have a significant impact on improving student learning outcomes.

Following the posttest, a student response questionnaire was administered to participants from SDN 01 Benteng Pasar Atas and SDN 03 Pakan Kurai to evaluate Digital Math Learning media effectiveness, focusing on material comprehension, interest, motivation, usability, interactivity, feedback, and learning outcomes. Based on the result of student response questionnaire assessment results (effectiveness questionnaire) above, a percentage of 96.08% was obtained, categorized as "Very High." Therefore, the interactive learning media Digital Math Learning is very effective.

Evaluation Stage

The evaluation phase of this study focused on assessing the quality of the interactive learning media, Digital Math Learning, through three main indicators: validity, practicality, and effectiveness. Evaluation was carried out continuously from the analysis stage to implementation. During the analysis stage, key issues were identified, including students' low understanding of mathematical concepts and the limitations of available digital media. Furthermore, the design phase resulted in a media design that took into account the material structure, visual appearance, and the integration of interactive features relevant to the learning objectives. The instrument was then validated by material, media, and language experts to ensure content suitability, format integration, and clarity of language use. Implementation was carried out through limited classroom trials, which aimed to assess the media's practicality and effectiveness. The evaluation results showed that the media had a very high level of feasibility, was engaging, easy to use, and proven effective in improving elementary school students' understanding and mathematics learning outcomes.

The development of interactive learning media, Digital Math Learning, in this study was carried out using the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. This model was chosen because it is systematic and structured in producing learning products that have been tested for validity, practicality, and effectiveness. During the analysis stage, it was found that fourth-grade elementary school students in the digital class had a high interest in interactive technology-based learning media, but experienced difficulties in understanding abstract mathematical concepts, especially those related to Plane Shapes. This finding confirms the view Hanifah et al., (2025) that varied, interactive, and student-specific media can aid conceptual understanding, increase learning motivation, and reduce boredom. Therefore, the development of Digital Math Learning is aimed at providing learning media that is not only adaptive to student needs but also relevant to the demands of the Independent Curriculum.

In the design phase, researchers developed a learning flow using flowcharts and storyboards to ensure consistency, logic, and integration between materials, activities, and evaluations. The microsite platform was chosen because it supports the integration of various learning resources, ranging from learning videos, interactive e-books, educational games, adaptive quizzes, and automated feedback-based assessments. The visual appearance was designed using harmonious colors, educational icons, and simple yet functional navigation. This aligns with the recommendations Wulandari et al., (2023) that effective learning media must have an attractive appearance, be easy to use, and be relevant to learning objectives.

The development stage involves producing multimedia content that combines text, images, animation, audio, and interaction. Multimedia learning principles are applied to ensure that the combination of various presentation formats strengthens conceptual understanding and

reduces students' cognitive load (Teguh Handoyo et al., 2024). The material is presented in stages, starting with an introduction to the concept, its application in everyday life, interactive simulations, and then through to automated feedback-based exercises. The integration of game-based learning elements is intended to encourage active student engagement, as supported by research Ananda et al., (2024) which confirms that educational games increase motivation and participation in mathematics learning.

The implementation stage conducted in digital elementary school classrooms in Bukittinggi demonstrated that the Digital Math Learning media significantly enhanced student engagement and conceptual understanding. Teachers reported that students found it easier to comprehend abstract mathematical concepts such as perimeter and area due to the use of visual simulations and interactive problem-solving exercises. However, further analysis revealed variations in outcomes based on students' ability levels. High-ability students utilized the adaptive quiz feature to deepen their understanding and self-correct through automated feedback. Medium-ability students benefited most from interactive simulations that clarified misconceptions about geometric properties, while low-ability students, although initially struggling with navigation, gradually improved through guided repetition and visual support. This phenomenon aligns with Vygotsky's Zone of Proximal Development (ZPD) theory, which asserts that structured digital environments can help learners of varying abilities progress within their potential range through scaffolding. The results indicate that this media not only improved learning outcomes (as reflected by an N-Gain value of 0.58) but also created a more equitable learning experience among students with different ability levels.

In terms of validity and practicality, expert assessments showed that Digital Math Learning achieved the "very valid" category based on evaluations by material, media, and language experts. Material experts confirmed that the content was aligned with the Independent Curriculum and relevant to students' real-life contexts. Media experts praised its interactivity and coherent design, while language experts ensured that the language used was communicative and age-appropriate for elementary students. These findings are consistent with Uljannah & Santoso (2024), who stated that effective learning media should combine relevant content, visual appeal, and high accessibility. The practicality test conducted with teachers and students also yielded a "very practical" rating. Teachers noted the media's ease of use, seamless integration with classroom activities, and adaptability to differentiated instruction. Meanwhile, students expressed satisfaction with its design, user-friendliness, and engaging game-based elements. According to Hidayat et al. (2025), practicality is a key factor for sustainable classroom use because it ensures that technology serves as a facilitator of learning rather than a barrier. From a constructivist perspective, such practicality allows students to focus their cognitive resources on meaning-making rather than technical difficulties.

Regarding effectiveness, quantitative data revealed an increase in the average pre-test score from 67.66 to 86.52 in the post-test, with an N-Gain of 0.58 (moderate category), indicating a significant improvement in learning outcomes. This increase suggests that digital interaction and automated feedback encouraged students' metacognitive reflection, enabling them to monitor and refine their understanding independently. These findings reinforce Mayer's Multimedia Learning Theory, which emphasizes that combining visual and verbal channels through feedback promotes deeper conceptual comprehension. Qualitatively, students demonstrated greater motivation and confidence in solving mathematical problems. The integration of game-based features fostered a mastery-oriented mindset rather than performance-based anxiety, consistent with constructivist learning theory, which views learners as active constructors of knowledge who continuously test and revise their cognitive structures.

Despite these positive outcomes, several implementation challenges were identified. First, teacher readiness varied, many educators lacked the competence to design, modify, or troubleshoot interactive media. This supports Kusnadi's (2024) assertion that the pedagogical impact of technology depends heavily on teacher preparedness and ongoing professional training. Second, infrastructure limitations, including unstable internet connections, limited device availability, and unequal digital literacy, continue to hinder large-scale adoption. Third, sustainability requires institutional support, particularly for integrating media into Learning Management Systems (LMS) and ensuring cross-device compatibility. To address these challenges, professional development programs focusing on Technological Pedagogical Content Knowledge (TPACK) are essential, enabling teachers to become not only users but also designers of digital learning experiences. Additionally, policy-level investments in digital infrastructure and curriculum alignment are critical to ensuring equitable access across schools.

The implementation of Digital Math Learning reflects the vision of the Independent Curriculum, which emphasizes student-centered, differentiated, and technology-integrated learning. The success of this media demonstrates that technology can enhance both academic achievement and positive attitudes toward mathematics. Beyond improving test scores, it fosters curiosity, perseverance, and digital literacy, key competencies for the 21st century. Therefore, this research provides empirical evidence that well-designed digital media, grounded in constructivist principles and multimedia learning theory, can effectively transform mathematics learning at the elementary school level.

Conclusion

Based on the research findings, it can be concluded that the development of the Digital Math Learning interactive learning media for Mathematics instruction in elementary school digital classes is highly valid, practical, and effective. The validity of the media is evidenced by expert assessments of content, media, and language, which were categorized as very valid. The practicality aspect was demonstrated through positive responses from teachers and students regarding its ease of use and engagement, while its effectiveness was reflected in a significant improvement in students' learning outcomes with a medium *N-Gain* value. The novelty of this study lies in the integration of a microsite platform, adaptive feedback, and gamification elements, creating an interactive, personalized, and enjoyable digital learning experience. The synergy of these components represents an innovation relevant to 21st-century learning needs and aligns with the principles of the Merdeka Curriculum.

The implication of this research suggests that teachers should utilize Digital Math Learning as a primary medium to foster engaging and adaptive learning environments. For curriculum developers, this media can serve as a model for implementing digital learning that promotes learner autonomy. Future research is recommended to extend the application of Digital Math Learning to other subjects or grade levels and to include innovative features such as *real-time feedback* to further enhance its effectiveness in improving the quality of digital learning in elementary schools.

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