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Development of Digital Comics Based on Local Wisdom to Improve Students' Mathematical Literacy Skills

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ABSTRACT

This study aims to develop a digital comic based on local wisdom to enhance the mathematical literacy skills of junior high school students. The research employed a Research and Development (R&D) approach using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Data collection techniques included both test and non-test instruments. The test instrument comprised a mathematical literacy assessment designed to measure students' mathematical literacy skills, while the non-test instruments included observation sheets, interview guidelines, student response questionnaires toward the digital comic, and validation sheets to assess the practicality and validity of the developed product. The validity and practicality data were analyzed using percentage techniques, while the effectiveness of the product was evaluated using the N-gain score. The findings indicate that the digital comic based on local wisdom achieved content and graphic component validity scores of 75.67% and 76.33%, respectively, categorized as "valid." Meanwhile, the presentation and language components received validity scores of 66.67% and 68.33%, categorized as "moderately valid." In terms of ease of use, visual appeal, and perceived usefulness, the instructional material was deemed "highly practical." Test results revealed that students' scores across all mathematical literacy indicators fell within the moderate category. Based on these findings, it can be concluded that the developed digital comic grounded in local wisdom is valid, practical, and effective for use in classroom instruction to enhance students' mathematical literacy. From a practical standpoint, this comic offers an engaging alternative for contextual learning media. Academically, the results underscore the importance of integrating local culture and visual media in the development of innovative instructional materials.

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A. INTRODUCTION

Mathematical literacy refers to an individual's ability to formulate, apply, and interpret mathematics in a variety of contexts. This competence involves mathematical reasoning as well as the use of concepts, procedures, and factual knowledge to describe, explain, or predict phenomena or events (OECD, 2019). According to the National Council of Teachers of Mathematics Reston (2000) mathematical literacy also encompasses the ability to understand, evaluate, and utilize mathematics in making everyday decisions, as well as the ability to clearly communicate mathematical thinking.

A key indicator of strong mathematical literacy is a student's capacity to formulate, identify, comprehend, and implement basic mathematical knowledge in diverse real-life situations to solve everyday problems (Haara et al., 2017). Additionally, mathematically literate students are expected to be able to use mathematics to describe, illustrate, or estimate various phenomena (Manoy & Indarasati, 2018; Nurutami et al., 2018).

Mathematical literacy is a crucial skill for students, as it enables them to apply mathematics in their daily lives (Dewantara et al., 2015; Hwang & Ham, 2021; Jannah et al., 2019; Malasari et al., 2017; Nizar et al., 2018; Rizki & Priatna, 2019). Stacey (2010) emphasizes that mathematical literacy is a key asset in preparing individuals to navigate modern society, beginning with simple day-to-day activities and extending to readiness for professional roles. Furthermore, Kusumah (2011) asserts that individuals with strong mathematical literacy skills are able to communicate effectively, make sound judgments, and appreciate the meaningful application of mathematics in various contexts.

Despite the recognized importance of mathematical literacy, this competency remains a significant challenge for Indonesian students, as reflected in the results of the Programme for International Student Assessment (PISA), which evaluates students' abilities in mathematics, reading, and science. The data indicate persistently low performance in mathematical literacy among Indonesian students. In PISA 2003, Indonesia ranked 38th out of 41 participating countries with an average score of 360. Although the score slightly improved to 391 in 2006 (ranking 50th out of 57 countries), it declined again to 371 in 2009, placing Indonesia 61st out of 65 countries, compared to the international average of 496. In 2012, Indonesia was the second-lowest performer, ranking 62nd out of 63 countries with a score of 375. The trend continued in 2015 with a score of 386 and dropped further in 2018 to 379. Most recently, in the 2022 PISA assessment, Indonesia's score decreased again to 366 significantly below the OECD average of 472 (OECD, 2023; Wijaya et al., 2024; Salistia et al., 2024; Masfufah & Afriansyah, 2021; Dewantara, 2019).

One of the key factors contributing to students' low mathematical literacy is the limited quality and variety of teaching materials used in schools. To date, teachers have primarily relied on government-provided resources or other instructional materials that emphasize mathematical concepts rather than promoting problem-solving skills necessary for developing mathematical literacy. This concern aligns with Khikmiyah & Midjan (2017) who argue that the lack of instructional materials specifically designed to enhance mathematical literacy contributes to students' underperformance in this area. In addition, students are often not exposed to contextual problems that demand higher-order thinking skills such as reasoning, argumentation, and creativity in problem-solving (Balitbang, 2011; Kurniawati et al., 2021).

Kusumah (2011) notes that most mathematics content in junior high school is predominantly numerical in nature**.** Consequently, the presentation of mathematical concepts is often closely tied to numerical manipulation, leading to the widespread misconception that mathematics is solely about numbers or arithmetic operations. This view is supported by Azmi et al. (2023) who argue that mathematics is frequently perceived as merely involving calculations and formulas. Similarly, Widjajanti (2009) emphasizes that an overreliance on numerical approaches in mathematics instruction tends to neglect essential components such as conceptual understanding, reasoning, and mathematical communication. This issue is

further reinforced by the findings of which show that students grasp mathematical ideas more effectively when the content is presented in real-life contexts, rather than through abstract calculation tasks. According to Putra et al. (2021), teaching materials that incorporate contextual problems and problem-solving strategies help students recognize the relevance of mathematics in various real-world situations. Therefore, it is imperative for teachers to select and develop instructional resources that not only present mathematical concepts but also foster students' mathematical literacy skills.

To enhance students' mathematical literacy skills, teachers can develop story-based content visualized through characters or figures rooted in local wisdom. This approach aims to stimulate students' curiosity and engagement with real-life problem contexts. One such medium that supports this type of learning is digital comics. Comics, as a blend of text and visuals, are typically structured in sequential panels that depict a storyline or scenario (Devi et al., 2020). The key elements of comics include plot, characters, panels or frames, dialogue and speech bubbles, as well as setting (Mudlaafar et al., 2019). The design of educational digital comics can be integrated with modern technologies such as Android applications and web-based platforms. Digital comics offer unique advantages, including the ability to present engaging, interactive, and contextually rich learning content thereby enhancing students' motivation and deepening their understanding of mathematical concepts (Asharimudin et al., 2022). According to Widodo et al. (2023), locally themed educational comics not only facilitate comprehension but also create an emotional connection with the material. Moreover, interactive digital comics have been shown to be effective tools for developing literacy and critical thinking skills, as they convey real-world contexts through accessible and visually appealing formats (Rahmawati & Salam, 2018).

The developed comics not only present instructional content but also explicitly aim to cultivate students' mathematical literacy skills through storylines embedded with contextual problems and formative feedback**.** Furthermore, the narratives are enriched with elements of local wisdom to enhance students' curiosity and engagement with the material. Local wisdom refers to the traditions and customs passed down through generations and preserved by specific local communities (Hasanah & Andari, 2021). It is manifested in various forms such as folktales, songs, proverbs, traditional advice, slogans, and ancient manuscripts, which are embedded in the daily lives of community members. Local wisdom is reflected in traditional cultural practices and represents the core values upheld by particular groups (Rohmah, 2019). In the context of this study, the local wisdom featured in the comics is drawn from the cultural heritage of Cimahi, which serves as the narrative foundation for the scenarios presented in the digital comic.

This research focuses on the development and evaluation of instructional materials in the form of digital comics that are not only visually engaging but also embed contextual and meaningful mathematical content**.** Through expert validation, limited field trials, and analysis of student learning outcomes, the study seeks to assess the quality and effectiveness of digital comics in the context of mathematics instruction. Accordingly, this research is expected to contribute to the innovation of teaching materials that effectively support the enhancement of students' mathematical literacy skills in ways that are both pedagogically sound and relevant to their everyday lives.

B. METHODS

This research is a development research that uses the ADDIE model which has five stages, namely: (1) Analysis, this stage is the initial stage to identify needs, student characteristics, learning objectives and problems that exist in learning; (2) Design, at this stage the learning plan is prepared; (3) Development, at this stage theoretical testing is carried out and development will be carried out based on the results from validators and practitioners; (4) Implementation, at this stage learning is carried out using the products that have been developed; and (5) Evaluation, assessment and feedback so that the product being developed is even better. The development process requires several tests by expert teams, individual research subjects, on a limited scale or a large scale (field) and revisions to perfect the final product (Cahyadi, 2019), as shown in Figure 1.

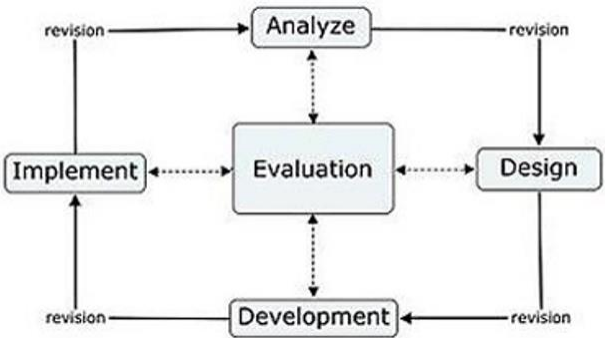

Figure 1. Alur Penelitian

The participants in this study included three experts, one practitioner, and 30 seventh-grade junior high school students**.** The selection of student participants was based on the following characteristics: (1) students demonstrated low levels of mathematical literacy; (2) students showed a greater interest in learning through visual and interactive media; and (3) students were still in the developmental stage of forming attitudes and interests toward mathematics.

Data collection techniques consisted of both test and non-test methods. The test technique involved the use of descriptive assessments to evaluate students' mathematical literacy skills. Meanwhile, non-test techniques included observations, interviews, and questionnaires to assess students' responses to the implemented teaching materials, as well as validation sheets to evaluate the practicality and validity of the developed materials. The criteria for evaluating the validity of the learning materials are presented in Table 1.

Table 1. Interpretation of Criteria for Assessing the Validity of Teaching Materials

No	Percentage	Validity Criteria
1	$75 < V \leq 100$	Valid
2	$56 < V \leq 75$	Quite Valid
3	$39 < V \leq 56$	Less Valid
4	≤ 39	Invalid

The developed learning materials will be evaluated for both validity and practicality by three experts and three practitioners**.** In addition to meeting validity standards, the instructional materials must also fulfill the criteria for practicality to ensure their applicability in real classroom settings. The criteria for assessing the practicality of the teaching materials are outlined in Table 2.

Table 2. Interpretation of Practicality Criteria for Teaching Materials

No	Percentage (P)	Practicality Criteria
1	84 < P ≤ 100	Very Practical
2	69 < P ≤ 84	Practical
3	54 < P ≤ 69	Moderately Practical
4	49 < P ≤ 54	Less Practical
5	≤ 49	Not Practical

The effectiveness test results were analyzed using the N-gain method, as proposed by Hake (Nissen et al., 2018).

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - minimum\ score} \quad (1)$$

The N-gain criteria are presented in Table 3 below.

Table 3. N-gain Category Guidelines

No	Score N-gain	Category
1	g ≥ 0,7	High
2	0,3 < g ≤ 0,7	Moderate
3	g ≤ 0,3	Low

The criteria for determining the success of the developed learning materials are that they meet the indicators of validity (valid or moderately valid), practicality (very practical, practical, or moderately practical), and effectiveness (high or moderate).

C. RESULT AND DISCUSSION

This study is a development research employing the ADDIE model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation**.** The primary aim of this research is to develop digital comics based on local wisdom to enhance the mathematical literacy skills of junior high school students. A description of each phase is presented as follow

1. Analysis Stage

The main activity in this phase is to analyze the need for developing digital comics based on local wisdom for educational purposes**.** Several analyses were conducted, including the following:

a. Problem Analysis

In this phase, the fundamental problems encountered in the learning process begin to surface**.** As previously outlined in the background, the primary rationale for developing this digital comic stems from the persistently low mathematical literacy skills among students, as evidenced by PISA results. Consequently, a strategic solution is required to

address this issue. The proposed solution should aim to enhance both teachers' and students' competencies in technology-integrated mathematics instruction that aligns with 21st-century educational demands. One potential approach to improving students' mathematical literacy particularly in the topic of fractions is to update traditional teaching materials and transform them into technology-based instructional resources.

b. Student Analysis

Student analysis involves examining learners' characteristics in terms of their knowledge, skills, and developmental stage**.** This analysis aims to identify the varying levels of student ability in order to align the teaching materials appropriately. The instructional materials developed in this study are intended for junior high school (SMP) students. This choice is grounded in Jean Piaget's theory of cognitive development, which posits that students at the junior high school level are generally in the formal operational stage. At this stage, learners are capable of employing cognitive structures to think abstractly, organize and reason through ideas, and formulate assumptions or hypotheses when solving problems. The digital comic-based teaching materials developed in this study require students to engage in abstract reasoning and connect prior knowledge with new information presented through interactive media. Therefore, selecting junior high school students as the target users is a theoretically justified decision, based on their developmental readiness as described by Piaget's framework.

c. Material Analysis

Material analysis involves identifying materials relevant to the development of the digital comic. In developing this digital comic, the material taken is material that is relevant to the use of technology.

d. Learning Outcome Analysis

Learning outcomes are an important aspect of learning and are used to measure the extent to which learning objectives have been achieved. In the fraction material, it can be seen that students' learning outcomes are still low, as seen from the daily test scores and mid-semester exams, which contain questions to measure mathematical literacy skills.

e. Teaching Materials Analysis

The teaching materials currently used by teachers consist of printed handouts containing summaries of the material and questions, which students find less meaningful. The content of the teaching materials used tends to be monotonous and does not lead to contextual matters, so that it is less understood by students. Therefore, the digital comic that will be developed contains contextual problems so that it is easy for students to understand.

f. Learning Objective Analysis

Learning objective analysis is a necessary step to determine the skills or competencies students need to acquire through the learning materials developed. In this digital comic design, the Basic Competencies (KD) and Junior High School Mathematics Indicators are formulated as shown in Table 4.

Table 4. Core Competencies and Indicators

Basic competencies	Indicator
Explain and determine arithmetic operations for whole numbers and fractions by utilizing various properties of operations	Determine the operations of adding and subtracting fractional numbers
Solve problems related to integer and fractional arithmetic operations	Presenting story problems related to fraction arithmetic operations

2. Design Stage

The design stage is the stage of designing teaching materials in the form of digital comics based on local wisdom. This design is carried out based on problem analysis, student analysis, material analysis, learning outcome analysis, teaching material analysis and learning objective analysis. The following is a digital comic design that was developed, as shown in Figure 2 and Figure 3.

Figure 2. Digital Comic Cover

Figure 3. One Part of Local Wisdom

Figure 3 is part of a digital comic that introduces local wisdom from Cireundeu Village, located in Cimahi City, West Java Province. In this section, children are invited to learn that the people of Cireundeu Village use cassava as their daily staple food because of its nutritional value and abundant availability. The cassava is processed into rice which is called rasi rice, as shown in Figure 4.

Figure 4. Pembagian Pecahan

Figure 4 is an example of a fraction division operation discussed in the digital comic. Of course, this comic is accompanied by answers and how to do it which is definitely easy for students to understand.

3. Development Stage

At this stage, theoretical testing is carried out, where the product will be validated by experts and practitioners. The expert validators were 3 lecturers in Mathematics Education who were relevant to their field of expertise. The following are the results of the expert assessment presented in Table 5.

Table 5. Expert Validation Results of the Teaching Materials

No	Assessed Aspect	Val 1	Val 2	Val 3	Average	Criteria
1	Content Validity	76%	78%	73%	75,67%	Valid
2	Presentation Component	68%	61%	71%	66,67%	Moderately Valid
3	Graphic Component	75%	76%	78%	76,33%	Valid
4	Language Component	60%	70%	75%	68,33%	Moderately Valid

Based on Table 5, the validation results for the digital comic show that the aspects of content validity and graphic components fall into the "valid" category, while the presentation and language components are categorized as "moderately valid." The suggestions provided by the expert validators are as follows:

a. Validator 1: The comic is fairly well-developed, but the integration of local wisdom is not yet clearly visible.
b. Validator 2: Overall, it is good, but it would be better if more examples were added.
c. Validator 3**:** The comic is well-developed.

In response to the experts' feedback, the researcher made several revisions to improve the product, which was still in the prototype stage. The following are the components that were revised based on the suggestions, as shown in Figure 5.

Figure 5. Digital Comic After Revision

In addition to being assessed by expert validators, digital comics are also assessed by practitioners. The following assessment results are presented in Table 6.

Table 6. Practitioner Validation Results

No	Assessed Aspect	P1	P2	P3	Average	Criteria
1	Ease of Use	85%	88%	82%	85%	Very Practical
2	Presentation Attractiveness	80%	85%	80%	81,67%	Very Practical
3	Usefulness	85%	86%	85%	85,33%	Very Practical

Based on Table 6, the aspects of ease of use, presentation attractiveness, and usefulness were all rated as "Very Practical" and are considered suitable for use in teaching fraction material. In addition, feedback from all three practitioners indicated that the digital comic was well-developed and did not require any further revisions.

4. Implementation Phase

At the implementation stage, the developed and validated digital comic is applied in a real classroom setting. The primary objectives of this phase are as follows:

a. To guide students in achieving the intended learning objectives,
b. To ensure that the digital comic helps address the learning difficulties previously encountered by students,
c. To verify that students' mathematical literacy skills improve by the end of the instructional process.

In this phase, the researcher employed a pre-experimental design using the one-group pretest–posttest design. A single class, namely Grade VII A, was selected as the experimental group. Prior to the implementation of the digital comic, students were given a mathematical literacy pretest that assessed five indicators: communication, mathematization, representation, reasoning and justification, and problem-solving strategies. After the instructional intervention using the digital comic, a posttest was administered to measure the improvement in students' mathematical literacy. The effectiveness of the product was then analyzed using the N-Gain score. The results of the product effectiveness test are presented, as shown in Table 7.

Table 7. Effectiveness Results

No	Mathematical literacy indicators	Total	Criteria
1	Communication	0,50	Moderate
2	Mathematization	0,68	Moderate
3	Representation	0,56	Moderate
4	Reasoning and Justification	0,40	Moderate
5	Problem-Solving Strategy	0,50	Moderate

Table 7 shows that all mathematical literacy indicators fall into the 'moderate' criteria, so it can be concluded that the local wisdom-based digital comics that were developed are effective in improving students' mathematical literacy skills.

5. Evaluation Stage

Evaluation is the final stage of the ADDIE teaching materials development model. Each stage of digital comic development involves evaluation. Evaluation takes the form of directions and improvements that must be made to obtain digital comics that are valid, practical and effective in developing mathematical literacy skills. Overall, the digital comics developed have met the criteria of being valid, practical, and effective. The digital comics developed are effective in improving students' mathematical literacy skills. By utilizing existing technology, the resulting comics can be created using existing software. Comics are read online via mobile phones in digital form. Comic media applied in digital form is easier to carry and more practical to use compared to paper or book form. The use of digital comics is very suitable for use as a learning medium, because it can encourage students to read. In research conducted by Gunadi & Aisyah (2019) it was stated that mathematics learning structured using learning media in the form of comics will be able to improve students' mathematical literacy skills. This is supported by research by Florayu et al. (2017) which states that the use of comic media can provide better improvements in student learning outcomes compared to the learning outcomes of students who study without using the comic media that has been developed. So it can be concluded that the learning process using comics can develop students' abilities by fostering motivation to learn and interest in learning so that it can improve literacy skills.

D. CONCLUSION AND SUGGESTIONS

Based on the research results, it can be concluded that: (1) Digital comics based on local wisdom have been proven valid and suitable for use in fraction learning with expert validation scores for the content component of 75.67% and graphics of 76.33% with a valid category, as well as presentation and language of 66.67% and 68.33% respectively with a fairly valid category; (2) Digital comics based on local wisdom are declared practical with a practicality score in the aspect of ease of use of 85%, attractiveness of presentation of 81.67%, and usefulness of 85.33%, all of which fall into the very practical criteria; (3) Digital comics based on local wisdom are effective in improving students' mathematical literacy skills, as seen from the average N-gain value being in the medium category, including mathematization of 0.68; representation of 0.56; communication and problem-solving strategies of 0.50; and reasoning and reasoning of 0.40. These findings confirm that the digital comics developed not only deliver material in an interesting and contextual manner, but also have a positive impact on student learning outcomes.

For further research, it is recommended that media development be expanded to other mathematical topics such as multiplication and division of fractions, geometry or algebra. Combining interactive elements such as animation, video and digital quizzes is also recommended to enrich the learning features of digital comics. In addition, exploring local wisdom from various regions in Indonesia can be an important direction in expanding the scope of content diversity, so that the comics developed are more inclusive and relevant to the characteristics of students in various regions.

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