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Comic-Based Microlearning Worksheets to Improve Elementary Students' Numeracy Skills and Motivation

Rita Ratna Sari[1*], Intan Dwi Hastuti[1], Zulkarnain[1], Moses Adeleke Adeoye[2], Zohaib Hassan Sain[3]
[1]Muhammadiyah University Mataram, Indonesia
[2]Al-Hikmah University, Ilorin, Nigeria
[3]Superior University, Pakistan
*Corresponding Author's email: ritartnsri.rrs@gmail.com

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Abstract

Numeracy skills and learning motivation are essential competencies; however, observations indicate that some students still struggle to understand arithmetic operations and are less engaged in learning environments dominated by conventional methods and minimal use of interactive media. This study aimed to analyze the effect of comic-based microlearning integrated with student worksheets on students' numeracy skills and learning motivation. The study employed a quantitative, quasi-experimental design, using a pretest-posttest control group for numeracy skills and a posttest-only control group for learning motivation, with 30 fourth-grade students in the limited sample, divided into experimental and control groups. Data were collected through numeracy tests and learning motivation questionnaires, then analyzed using normality tests, homogeneity tests, t-tests, and N-Gain. The results showed that the data were normally distributed and homogeneous $p > 0.05$, and there was a significant difference between the two groups $p < 0.001$ with an N-Gain value of 0.5748 in the moderate category. This study suggests that integrating comic-based microlearning into student worksheets can serve as an innovative instructional design that engages cognitive and affective aspects through the presentation of structured material and visual narratives, thereby supporting improvements in students' numeracy understanding and learning motivation.

INTRODUCTION

Background of the Study

Numeracy is a concept that encompasses the skills to access, utilize, and critically reason with mathematical content, information, and ideas presented in various forms to meet the mathematical demands of life (Díez-Palomar et al., 2023). Mastery of numeracy is a basic competency that students must possess from the elementary school level, as it extends beyond calculation skills to include the ability to think logically, analytically, and critically. In the context of 21st-century education and the implementation of the Merdeka Curriculum, numeracy skills play an important role in shaping students who are critical thinkers and adaptable (Deslis et al., 2025; Hsu et al., 2022; Wang et al., 2022). Improving numeracy skills is closely related to students' affective aspects, particularly learning motivation, as an internal drive to participate in the learning process actively (Itu et al., 2024; Wang et

al., 2021). This motivation grows when students are involved in learning situations that are interesting, interactive, and relevant to their experiences. Unlike learning motivation, which is oriented towards academic achievement, learning motivation emphasizes educators' strategies for creating a pleasant learning environment. The synergy between learning motivation and numeracy mastery is mutually reinforcing: high motivation encourages active involvement, while strong numeracy skills increase students' self-confidence (Kong, 2021; Yonanada et al., 2024).

Student Worksheets are systematically organized sets of activities designed to help students understand concepts through focused, reflective learning (Irdalisa et al., 2024; Paspania & Susilawati, 2024). When integrated with the comic microlearning approach, Student Worksheets become more adaptive to the characteristics and learning needs of elementary school students. Microlearning is a technology-supported, action-oriented learning format that simplifies complex information into concise, focused, and easy-to-understand material through goal setting, content segmentation, visual presentation, interactive activities, and rapid feedback (Alias & Razak, 2023; Hendrastuti & Rahmawati, 2023). Comics are visual narrative media that combine illustrations and short texts to convey learning messages in an engaging, contextually relevant way. In the context of elementary school learning, the use of comics plays a strategic role by concretizing abstract concepts through visual representations that are easier for students to understand. Character elements, storylines, and simple dialogue in comics can increase students' attention, interest, and involvement in the learning process. In addition, comics align with visual learning styles and help students gradually understand information through the presentation of structured stories. Therefore, the use of comics as a learning medium not only increases the attractiveness of the material but also deepens the understanding of concepts and supports the creation of meaningful learning in accordance with the cognitive development of elementary school students (Pratiwi et al., 2025; Puspitasari & Rodiyana, 2022).

Problem of the Study

The variation in students' numeracy skills in this school is quite striking: some students have mastered basic numeracy, while others still have difficulty solving simple problems. There is also one student with special needs who needs material adjustments, but shows enthusiasm when learning using digital media. In addition, the application of conventional learning methods tends to make students less active, even though some students are starting to get used to using technology in learning activities. This condition is in line with the results of research, which shows that the numeracy skills of elementary school students is still in the medium to low category, especially in understanding concepts and solving contextual problems (Susilowati & Muhammad, 2025; Wijaya et al., 2020). In addition, the use of less varied learning media also contributes to low student involvement and participation in the learning process.

On the other hand, the dominance of conventional learning methods suggests that the learning strategies applied are not fully able to accommodate the diversity of students' characteristics and learning needs. This condition affects students' motivation and active involvement in the learning process. Studies have shown that less interactive learning approaches tend to hinder student participation, while appropriately designed technology integration can increase student engagement and learning independence (Alfiah et al., 2020). Therefore, more adaptive, interactive, and contextually relevant learning innovations are needed to improve the numeracy skills of elementary school students.

Research's State of the Art

Student Worksheets are systematically compiled to help students understand concepts through directed, structured, and reflective learning activities. Conceptually, Student Worksheets serve as a learning guide that supports independent knowledge construction. Its important elements include gradual, activity-based assignment presentation, and encouraging active student participation. The benefits of using Student Worksheets include increasing learning independence, critical thinking skills, and a deeper understanding of concepts (Sujiarto et al., 2025; Juliantari & Wibawa, 2024).

Comic media is a visual learning medium that combines illustrations, text, and storylines to convey material in an engaging, contextual way. Comics serve as a visual narrative medium that can help students understand abstract concepts make easily. The main features of this medium include the dominance of visual elements, a simple storyline, and dialogue that is easy to capture. The media can gradually increase students' interest, attention, and understanding of concepts as they develop (Rina et al., 2020; Sumilat et al., 2022).

Microlearning is a technology-based learning approach that presents material in small, focused, and accessible units. This approach highlights material segmentation, short learning duration, the use of digital media, and the provision of quick feedback. Microlearning is designed to provide a short but effective learning experience, improving information retention, flexibility, and student engagement in the learning process. Various studies show that microlearning can improve understanding of concepts while also motivating students significantly (Balasundaram et al., 2024; Leong et al., 2021; Oyeyipo et al., 2024; Sankaranarayanan et al., 2023; Zarshenas et al., 2022).

Numeracy skills are competencies that include the ability to understand, use, and interpret mathematical concepts in various contexts of daily life. These skills indicators include quantitative information processing, contextual problem solving, and the application of logic and analysis in decision-making. Mastery of numeracy is important because it supports critical thinking, problem-solving skills, and the skills to make informed decisions (Hidayat et al., 2022; Tang et al., 2022). Learning motivation in elementary school students is an internal and external drive that affects student participation and involvement in the learning process. Signs of high learning motivation include interest, attention, and a desire to achieve learning goals. Strong motivation to learn can increase active participation, perseverance, and student learning outcomes. The microlearning approach is proven to strengthen intrinsic motivation through adaptive digital interactions (Hidayat et al., 2023; Yin et al., 2020).

Komariyatiningsih et al. (2025) noted that the use of microlearning-based Student Worksheets can improve learning outcomes and student engagement. The integration of comic-based microlearning into Student Worksheets creates visual, interactive, and gradual learning media that are effective in increasing the motivation and numeracy skills of elementary school students. Observations at school show that students are more enthusiastic when learning with visual media, including a student with special needs. Interactive visual media such as videos and e-comics have been proven to strengthen students' engagement, conceptual understanding, and critical thinking skills, underscoring that integrated and contextual media can increase numeracy and learning motivation among elementary school students (Priyadi & Kuswanto, 2023).

Gap Study and Objective

Various studies show that applying Problem-Based Learning (PBL) can increase students' independence and active participation in the learning process (Isler et al., 2020; Maskur et al., 2020; Parwata et al., 2023). In addition, Pramasdyahsari et al. (2023) emphasize that the use of digital media supports students' learning independence and that microlearning strategies are effective in increasing learning motivation by delivering short, focused, and easy-to-understand material. The use of comics as a learning medium can also strengthen understanding of concepts in a more engaging, contextual way. However, these studies still tend to be carried out separately and have not integrated student worksheets, microlearning, and comics in a comprehensive learning design, especially at the elementary school level.

Mayadesti et al., (2025) stated that the application of interactive digital media in elementary schools remains limited, so the potential for student involvement in learning is not fully realized. In addition, previous research generally only focused on one aspect of learning outcomes, both cognitive and affective, so it did not provide a comprehensive picture of the influence of learning on numeracy skills and student motivation simultaneously (Hartono et al., 2025; Rahmawati, 2022). Other findings also show that the development of innovative learning media in elementary schools continues to face various obstacles in practice (Rahayu, 2024). Therefore, this study aims to analyze the influence of integrating Student Worksheets with comic-based microlearning on students' numeracy skills and

learning motivation, and to contribute to the development of innovative learning media relevant to the educational needs of elementary schools.

METHOD

Type and Design

This study uses a quantitative, quasi-experimental design. Numeracy skills were measured using a pretest-posttest control-group design to identify changes in students' skills before and after treatment. Meanwhile, learning motivation was measured using a posttest-only control group design, as the pretest was not administered to avoid bias from repeated questionnaires and to maintain the naturalness of students' responses to the learning process. Therefore, changes in students' learning motivation cannot be observed directly. The overall research stages are presented in Figure 1.

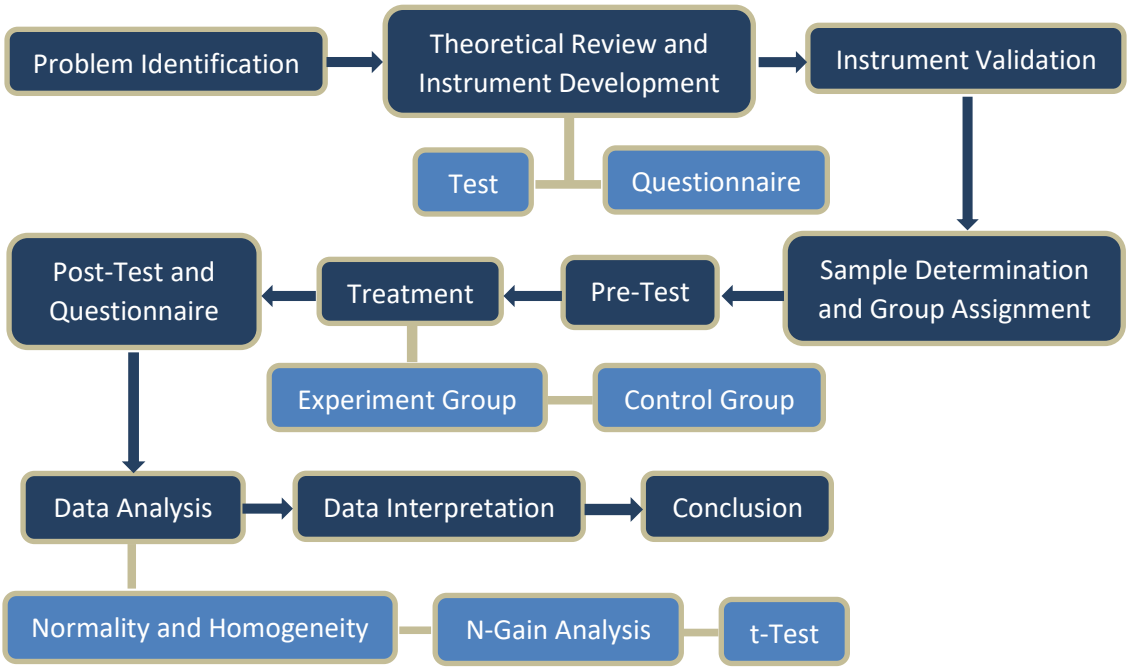


Figure 1. Research Internships

This study employed a quasi-experimental design with two groups: an experimental and a control. Treatment was delivered through the application of comic-based Student Worksheets (microlearning) as independent variables, while numeracy skills (Y_1) and learning motivation (Y_2) served as dependent variables. The experimental group received learning that integrated comic-based microlearning with student worksheets, while the control group received conventional student worksheets. This design allows the evaluation of the effect of treatment on students' numeracy skills and learning motivation by comparing the results of the two groups. Details of the research design for measuring numeracy skills are presented in Table 1.

Table 1. Pretest-Posttest Control Group Design

Group	Pretest	Treatment	Posttest
A	O_1	X	O_2
B	O_3	-	O_4

Table 1 shows that group A is the experimental group that applied comic-based microlearning Student Worksheets, while group B is the conventional control group. O_1 and O_3 describe the initial skills of students in both groups, as measured by a preliminary test, while O_2 and O_4 show the final test results of the experimental and control groups after the treatment (Hastuti et al., 2020).

Data and Data Sources

This study uses a quantitative, quasi-experimental design to compare learning outcomes between the experimental and control groups. The population in this study comprises all grade IV students at SD Negeri 03 Ampenan, totaling 59 students, of whom 32 are male and 27 are female, with an age range of 9-10 years. In general, the population has relatively homogeneous characteristics, both in terms of curriculum, basic numeracy skills, and classroom conditions and learning facilities, thus supporting the consistent implementation of research. This study involved 30 grade IV students as a limited purposive sample. The sample was then divided into two groups: 15 students in the experimental group and 15 in the control group. The selection of the sample was based on several criteria, including equal student initial abilities, the use of the same teachers, and relatively homogeneous classroom conditions, including the number of students, facilities, and the learning atmosphere. The determination of the experimental and control groups based on these criteria is intended to minimize potential bias while maintaining the internal validity of the research.

The treatment in this study is the application of microlearning comic-based Student Worksheets as the independent variable. The experimental group learned through microlearning integrated with student worksheets, while the control group used conventional student worksheets. The dependent variables measured in this study included numeracy skills (Y_1) and learning motivation (Y_2). Numeracy skills was measured through tests at the pretest stage before treatment and the posttest stage after treatment. The motivation to learn was measured using a questionnaire administered after the posttest. The data collection instruments in this study consisted of a numeracy test and a learning motivation questionnaire. The assessment of the numeracy test is based on several aspects, namely problem understanding, strategy and reasoning, solution steps, and calculation accuracy, with a score range of 1-4 in each aspect. Meanwhile, the learning motivation questionnaire was compiled using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), with star symbols to make it easier for elementary school students to understand. Positive items are scored according to the respondents' choices, while negative items are scored inversely. The scores from both instruments were then summed and analyzed.

Data Collection Technique

Before being employed in the research process, all research instruments were first subjected to expert validation (expert judgment). The validation process was conducted using an evaluation questionnaire comprising 12 statement items, rated on a scale from 1 to 5. The validators involved in this study included one lecturer, serving as a subject-matter expert, and one homeroom teacher, who acted as a language validator and a practicing educator at the school where the research was conducted. The instruments validated in this study included a numeracy test, student worksheets integrated with comic-based microlearning, and a student learning motivation questionnaire, as presented in Table 2.

Table 2. Results of Instrument Validation

1.	**Material Expert Validation Results**		
	Aspects Evaluated	**Percentage**	**Category**
	Alignment of learning materials	88%	Highly valid
	Alignment of learning indicators	86%	Valid
	Quality of test items	87%	Valid
	Content feasibility of the student worksheets	87%	Valid
	Suitability of the questionnaire instrument	87%	Valid
	Average	**87%**	**Valid**
2.	**Language Validation Results**		
	Aspects Evaluated	**Percentage**	**Category**
	Clarity of language use	85%	Valid
	Level of readability	84%	Valid
	Clarity of learning instructions	84%	Valid
	Appropriateness of language in the questionnaire	83%	Valid

Suitability with students' characteristics	84%	Valid
Average	**84%**	**Valid**

Table 2 presents the results of the validators' assessments of the research instruments. Based on these results, the average validation percentage for the material aspect was 87%, indicating that the alignment of the learning materials, learning indicators, and the construction of test items and activities in the student worksheets was consistent with the intended learning objectives. Meanwhile, the language aspect achieved an average of 84%, suggesting that the instruments' language demonstrated good readability and was appropriate for elementary school students. Therefore, all research instruments were deemed feasible for use after minor revisions were made in accordance with the validators' suggestions and subsequently adjusted to align with the number of research indicators, as presented in Table 3.

Table 3. Research Instrument Indicators

Numeracy Skills (Y1) Indicators s (Winata et al., 2021)	**Description**
1. Able to use basic mathematical numbers and symbols to solve everyday problems, streamlining routine tasks efficiently.	1) Demonstrates strong proficiency in analyzing and solving diverse addition and subtraction problems. 2) Able to apply addition and subtraction accurately in real-life problems
2. Able to read and understand information in various forms, enabling informed choices and practical action.	1) Able to explain increases or decreases in data using addition and subtraction concepts to communicate data shifts clearly.
3. Able to interpret analysis results to make estimates and decisions	1) Skilled at determining final totals or differences from calculation results, providing clear numerical insights. 2) Able to estimate the results of increasing or decreasing patterns, anticipating future trends for proactive planning.
Learning Motivation (Y2) Indicators (Arifin & Abduh, 2021)	**Description**
1. Students actively engage in learning tasks during the learning activities.	1) Following the teacher's instructions, assignments are completed on time. 2) Focus is maintained during lessons, and tasks are completed independently. 3) A responsible attitude is consistently demonstrated.
2. Students are involved in the problem-solving process during learning.	1) Problems given are understood, and solutions are actively pursued. 2) An active effort is made to find answers to encountered problems.
3. Students ask their friends or teachers when they do not understand the material or encounter difficulties.	1) Questions are asked clearly when the material is not understood. 2) Additional explanations are sought from friends or teachers when difficulties arise.
4. Students try to find the information they need to solve the problems they face.	1) Appropriate information is selected to answer questions accurately. 2) Information found is used to complete tasks accurately.

Data Analysis

Furthermore, according to Islahudin et al. (2020), the data were analyzed descriptively to examine trends and average learning outcomes, and the normalized gain score <g> was calculated to measure the increase in learning outcomes after treatment. This value indicates the effectiveness of learning, where improvement is considered good if <g> is greater than 0.40. For interpretation, the <g> results are grouped into three categories as shown in Table 4.

Table 4. Normalized Gain Score Categories

Range	Category
0.00 < <g> < 0.30	Low
0.30 < <g> < 0.70	Medium
0.70 < <g> < 1.00	High

To determine the increase in numeracy skills and learning motivation after treatment, an independent-samples t-test was used. Data analysis was performed using SPSS, beginning with normality tests (Shapiro-Wilk $p > 0.05$) and homogeneity-of-variance tests (Levene's Test $p > 0.05$). The results of these two tests served as the basis for the t-test, in which differences were considered significant if $p < 0.05$ and insignificant if $p \geq 0.05$. The final stage of the study included interpreting the analysis results and drawing conclusions about the effectiveness of using comic-based microlearning Student Worksheets in improving the numeracy skills and learning motivation of elementary school students.

RESULTS

This section may be divided by subheadings. It should provide a concise, precise description of the experimental results, their interpretation, and the conclusions that can be drawn. An initial overview of the research data was obtained through descriptive statistical analysis to identify trends in data distribution and average values. This analysis was conducted on pretest and posttest data from the experimental and control classes to measure the increase in numeracy skills (Y_1) following the application of Student Worksheets integrated with comic microlearning (X) during learning. The pretest data represented the students' initial skills before the treatment, while the posttest data showed the development of their skills after the learning intervention. Learning motivation (Y_2) was measured through a questionnaire given at the end of the learning process. A comparison of the pretest and posttest numeracy achievement of the experimental and control classes is presented in Table 5.

Table 5. Descriptive Statistics of Numeracy Skills

Numeracy Skills	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
N	15	15	15	15
Red	56.27	73.20	49.33	67.47
Standard Deviation	8.779	1.859	12.938	4.207
Variance	77.067	3.457	167.381	17.695
Minimum	42	70	31	57
Maximum	71	77	66	74

Table 5 shows that the experimental group experienced a significant improvement in numeracy skills (Y_1) after receiving the instructional intervention. This is evidenced by an increase in the mean score from 56.27 to 73.20, accompanied by a decrease in the standard deviation from 8.779 to 1.859. Additionally, the score range also shifted, with the minimum and maximum scores increasing from 42-71 on the pretest to 70-77 on the posttest. This indicates that students' learning outcomes became more consistent or homogeneous after the intervention was administered.On the other hand, the control group also experienced an improvement in numeracy skills, but with a relatively lower rate of increase. These findings suggest that the instructional intervention applied to the experimental group was more effective in improving students' numeracy skills compared to the control group. A summary

of the pretest & posttest scores in the experimental and control classes for the Numeracy Skills (Y_1) variable is shown in Figure 2.

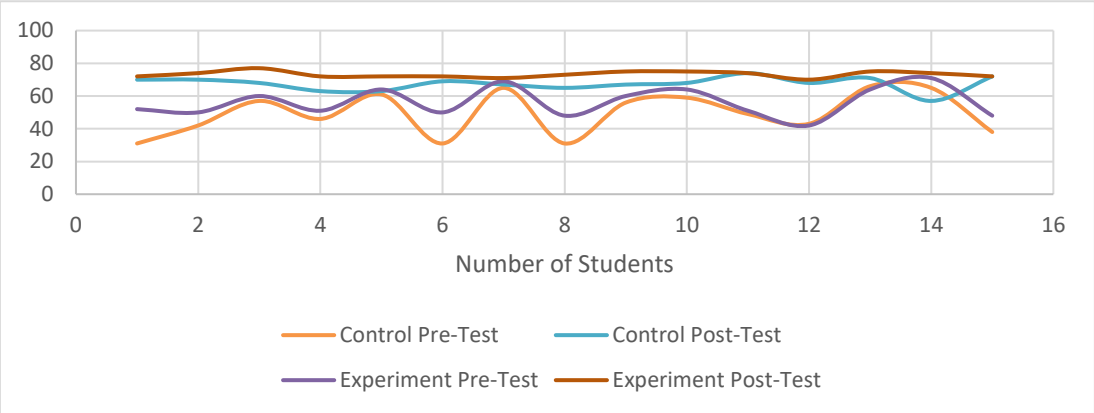


Figure 2. Numeracy Skill Scores

Figure 2 shows a comparison of pretest and posttest scores for numeracy skills (Y_1) in the experimental and control classes. Visually, the posttest results in both classes show an increase compared to the pretest, but the experimental class shows a more stable curve and a higher score level. In contrast, the posttest curve in the control class shows a wider spread of scores, indicating that the students' numeracy skills are not evenly distributed. The learning motivation (Y_2) achievements of the experimental class and the control class are presented in Table 6.

Table 6. Descriptive Statistics of Learning Motivation

Learning Motivation	Experimental	Control
N	15	15
Red	49.20	39.40
Std. Deviation	2.981	2.694
Variance	8.886	7.257
Minimum	46	33
Maximum	55	43

Table 6 Learning Motivation (Y_2) shows that students in the experimental class had an average score of 49.20 with a standard deviation of 2.981 and a variance of 8.886, indicating a relatively small level of variation in learning motivation. The minimum value of 46 and the maximum value of 55, with a range of 9, indicate that students' learning motivation achievements are relatively evenly distributed at a high level. In the control class, the average learning motivation score of 39.40 was lower than that of the experimental class, with a standard deviation of 2.694 and a variance of 7.257. The minimum score of 33 and the maximum score of 43, with a range of 10, indicate that the distribution of student learning motivation was lower. The learning motivation (Y_2) of students in the experimental class was higher and relatively even compared to the control class. Conversely, students in the control class showed a tendency for lower learning motivation. A summary of the scores in the experimental class and control class for Learning Motivation (Y_2) is shown in Figure 3.

Figure 3 presents the Learning Motivation scores (Y_2) for students in the experimental and control classes based on questionnaire results. Visually, the motivation scores in the experimental class are higher than those in the control class, with most students showing moderate to high achievement. In contrast, the motivation scores of students in the control class tended to be concentrated at a moderate level, indicating a difference in learning motivation between the two classes. To ensure that the inferential statistical assumptions were met, a normality test was conducted on Numeracy Skills (Y_1) and Learning Motivation (Y_2) for the experimental and control groups, as shown in Table 7.

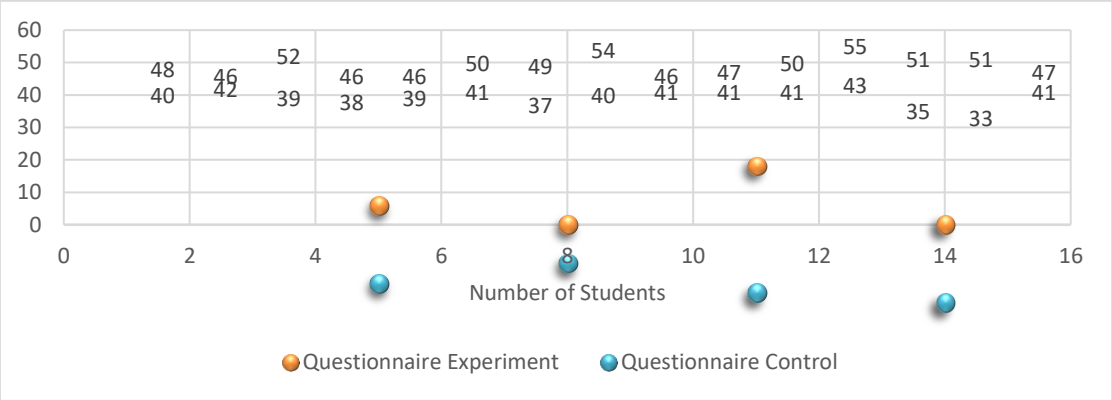


Figure 3. Learning Motivation Scores

Table 7. Test of Normality of Numeracy Skills and Learning Motivation

	Group	Test	Shapiro-Wilk Statistic	df	Sig	Description
Numeracy	Experiment	Pretest	0.908	15	0.128	Normal
		Posttest	0.948	15	0.491	Normal
	Control	Pretest	0.919	15	0.186	Normal
		Posttest	0.938	15	0.362	Normal
Motivation	Experiment	Posttest	0.905	15	0.112	Normal
	Control	Posttest	0.891	15	0.070	Normal

Table 7 presents the results of the Shapiro-Wilk normality test for Numeracy Skills (Y_1) and Learning Motivation (Y_2) data in the experimental and control classes. In the Numeracy variable, the experimental group obtained a significance value of 0.128 in the pretest and 0.491 in the posttest. In contrast, the control group obtained a significance value of 0.186 in the pretest and 0.362 in the posttest. As for the Learning Motivation variable, the posttest significance value in the experimental group was 0.112, and in the control group, 0.070. All significance values are above the 0.05 significance level, so it can be concluded that the data for both variables are normally distributed and meet the normality assumptions for parametric statistical analysis. Furthermore, the homogeneity of variance for Numeracy Skills (Y_1) and Learning Motivation (Y_2) data across groups was assessed using the Levene test, with the results presented in Table 8.

Table 8. Test of Homogeneity of Numeracy Skills and Learning Motivation

	Group	Test	Living Statistic	df1	df2	Sig	Description
Numeracy	Experiment	Pretest	3.720	1	28	0.064	Homogeneous
		Posttest	3.248	1	28	0.082	Homogeneous
	Control	Pretest	3.105	1	28	0.089	Homogeneous
		Posttest	3.850	1	28	0.060	Homogeneous
Motivation	Experiment	Posttest	0.542	1	28	0.468	Homogeneous
	Control	Posttest	0.618	1	28	0.442	Homogeneous

Table 8 presents the results of the variance homogeneity test using the Levene Test on pretest and posttest data on numeracy skills (Y_1) and learning motivation (Y_2) in experimental and control group. All significance values were above 0.05, indicating that the variance between groups was homogeneous. In the numeracy variable, the experimental group obtained a Levene statistical value of 3.720 with a significance of 0.064 in the pretest and 3.248 with a significance of 0.082 in the posttest.

In contrast, the control group obtained a value of 3.105 with a significance of 0.089 in the pretest and 3.850 with a significance of 0.060 in the posttest. For the learning motivation variable, the experimental group showed a value of 0.542 (p=0.468), while the control group showed a value of 0.618 (p=0.442). Thus, the data for both variables have homogeneous variances and meet the assumptions for proceeding to the next statistical analysis. Furthermore, the improvement of students' numeracy ability was analyzed using the N-Gain presented in Table 9.

Table 9. N-Gain Numeracy Skills

Category	N	Minimum	Maximum	Red	Standard Deviation
N-Gain Score	30	-0.53	0.85	0.5748	0.2996

Table 9 presents the N-Gain calculation results for students' numeracy skills (Y_1) from the pretest to the posttest. The analysis results show that the N-Gain values range from -0.53 to 0.85 with an average of 0.5748 and a standard deviation of 0.2996. This average value falls within the moderate range of the N-Gain score (0.30-0.70). The recorded N-Gain score range is quite diverse, indicating variations in the improvement of numeracy skills among students. In the experimental class, the application of Integrated Microlearning Comic Student Worksheets on Numeracy Skills produced higher N-Gain values than the control class. To assess the significant difference in Numeracy Skills (Y_1) and Learning Motivation (Y_2) between the experimental and control classes, an independent-samples t-test was conducted on the posttest data presented in Table 10.

Table 10. T-test for Numeracy Skills and Learning Motivation

	Group	Test	N	Red	Std. Deviation	Std. Error Mean	t-test Equality of Means t	df	Sig.
Numeracy	Experiment	Pretest	15	55.67	9.619	2.484	-1.407	28	0.085
	Control	Pretest	15	49.47	14.091	3.638			
	Experiment	Posttest	15	73.20	1.859	0.480	-4.828	28	<0.001
	Control	Posttest	15	67.47	4.207	1.086			
Motivation	Experiment	Posttest	15	49.20	2.981	0.770	-9.447	28	<0.001
	Control	Posttest	15	39.40	2.694	0.696			

Table 10 presents the results of an independent sample t-test on the scores of Numeracy Skills (Y_1) and Learning Motivation (Y_2) between the experimental class and the control class. In the pretest numeracy data, the experimental class had an average score of 55.67 with a standard deviation of 9.619, while the control class had an average score of 49.47 with a standard deviation of 14.091. The results of the t-test showed a t-value of t = -1.407 with df = 28 and a p-value of 0.085, indicating no significant difference and suggesting that the initial abilities of the two groups were equal. In the posttest numeracy data, the experimental class had an average score of 73.20 (SD = 1.859), while the control class had an average score of 67.47 (SD = 4.207). The t-test yielded t = -4.828, df = 28, and p < 0.001, indicating a significant difference. For the learning motivation variable, the experimental class had an average score of 49.20 with a standard deviation of 2.981, while the control class had an average score of 39.40 with a standard deviation of 2.694. The t-test yielded t = -9.447, df = 28, and p < 0.001, indicating a significant difference. These results confirm a difference between the experimental class and the controls in numeracy skills and learning motivation after the treatment was administered.

DISCUSSIONS

The study found that integrating student worksheets with comic-based microlearning significantly improved elementary school students' numeracy skills. This is shown by the increase in the average score in the experimental class from 56.27 to 73.20, which is higher than that of the control class, from 49.33 to 67.47, and is supported by a significance value of $p < 0.001$. These findings indicate that integrating comic media with a microlearning approach can facilitate a more systematic understanding of mathematical concepts. Theoretically, these results are in line with Cognitive Load Theory, which states that presenting material in small, visual units can reduce cognitive load and improve learning effectiveness (Sweller, 1994). These findings are also consistent with Alhadoor et al. (2023) and Rani et al. (2025), which show the effectiveness of visual-based learning in improving students' understanding of mathematical concepts.

In addition to the increase in average scores, the decrease in standard deviation in the experimental group from 8.779 to 1.859 showed that student learning outcomes became more homogeneous after the implementation of the learning intervention. This condition indicates that the approach used not only improves academic achievement but also reduces the skills gap between students. Meanwhile, in the control group, the standard deviation decreased from 12.938 to 4.207, but the level of variation in learning outcomes remained higher than in the experimental class. These findings align with research by Supriyadi et al. (2022) and Agustina & Ardhiani (2023), which indicate that the use of visual and interactive media can improve the equitable distribution of student learning outcomes and that technology-based learning is effective in helping students with low skills achieve a more optimal understanding.

Based on the effectiveness of the skills enhancement, the N-Gain analysis showed an average value of 0.5748, which falls in the medium category. This score indicates that learning interventions make a fairly effective contribution in improving students' numeracy skills. The variation in N-Gain values, ranging from -0.53 to 0.85, showed differences in the level of improvement between students, but, in general, improvement was more pronounced in the experimental group. It shows that the microlearning approach provides students with the flexibility to learn at their own pace and in their preferred learning style. These findings are supported by research by Jahnke et al. (2020), which states that microlearning effectively enhances learning by presenting short, focused, and structured material. In addition, Nikou & Economides (2018) emphasized that digital-based microlearning has a positive impact on student learning outcomes.

Regarding learning motivation, the results showed that students in the experimental class had an average motivation score of 49.20, higher than the control class's 39.40, with a significant difference ($p < 0.001$). These findings show that the use of comic-based microlearning increases students' learning motivation. Presenting material in an attractive visual narrative can increase student involvement and create a more enjoyable learning atmosphere. These results are in line with research by Hidayat et al. (2024) and Ryan & Deci (2020), which state that students' intrinsic motivation can be enhanced through engaging and relevant learning. In addition, Dichev & Dicheva (2019) show that visual- and gamification-based approaches are effective in increasing student engagement and learning motivation. These findings indicate that the implementation of comic-based microlearning can increase student engagement and enthusiasm in the learning process, as shown in Figure 4.

Furthermore, the increase in learning motivation can be explained through a visual narrative approach that integrates story and illustration elements in the learning process. This approach allows students to understand mathematical concepts in a more contextual and meaningful way, while improving their retention of the material. These findings are in line with research by Slips et al. (2025) and Ortegón Ángel et al., (2026), which show that digital storytelling can significantly increase student engagement and understanding, and also confirm that story-based media is more effective in improving elementary school students' understanding of mathematics concepts than conventional methods.

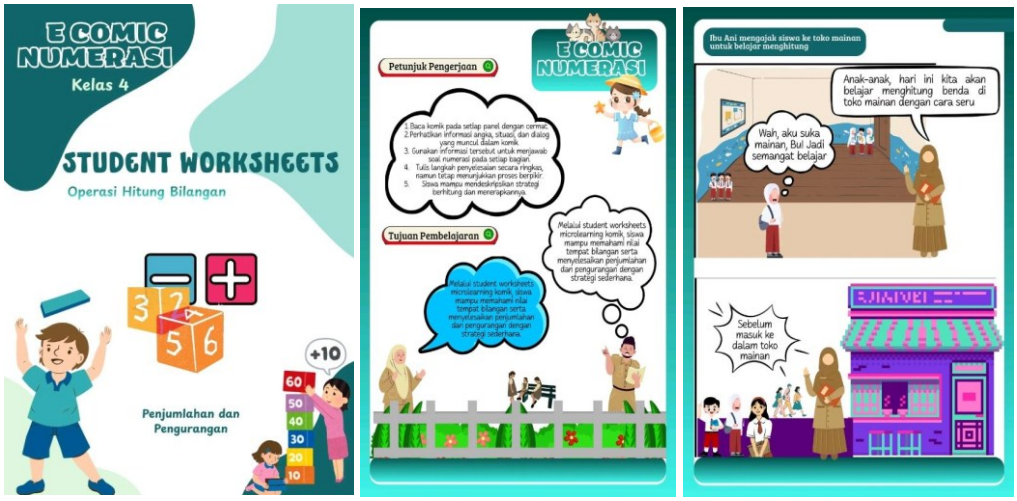
From the perspective of learning interaction, the application of comic-based microlearning also encourages social interaction between students through discussion, collaboration, and the exchange of ideas in solving problems. This activity plays an important role in improving mathematical communication skills while deepening students' understanding of concepts. These findings are

supported by research by Gillies (2020) and Suprihatin et al., (2023), which state that collaborative learning can significantly improve student learning outcomes and engagement. In addition, Järvelä et al. (2020) emphasize that social interaction in learning contributes to improving the quality of students' understanding.

Figure 4. Implementation of comic-based microlearning

In addition, the structured learning design in student worksheets also contributes to improving the quality of the learning process. The systematic, gradual presentation of the material helps students understand concepts more deeply and develop problem-solving skills. These findings align with Talkhan et al. (2025) research, which shows that structured learning strategies significantly improve learning outcomes. In addition, Fiorella & Mayer (2020) state that directed, systematic learning can enhance the effectiveness of mathematics learning. The use of comic-based student worksheets as a structured learning medium is shown in Figure 5.

Overall, the results of this study show that integrating student worksheets with comic-based microlearning significantly improves numeracy skills, learning motivation, and the equitable distribution of learning outcomes among elementary school students. These findings reinforce previous research emphasizing the importance of using visual media, innovative approaches, and structured learning strategies to improve the quality of mathematics learning. Compared to previous research, the approach in this study has the advantage of integrating microlearning, comic media, and worksheets into a single systematic learning design, thereby improving learning outcomes in both cognitive and affective domains simultaneously. In addition, Schindler et al. (2019) and van Alten et al. (2020) emphasized that integrating multimedia into learning has a significant impact on students' understanding and motivation to learn.



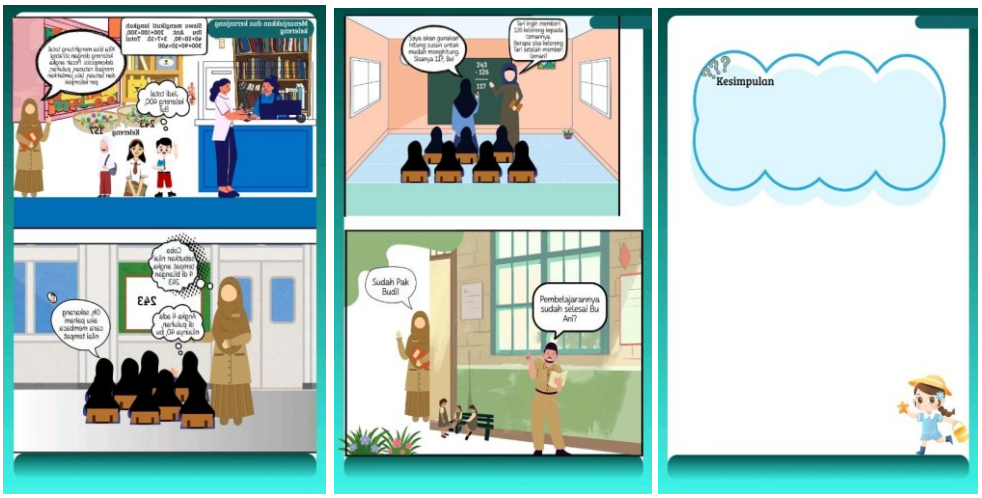


Figure 5. Comic-Based Student Worksheets as a Learning Medium

CONCLUSION

The results of this study show that the implementation of comic-based microlearning integrated with student worksheets has a significant effect on improving numeracy skills and learning motivation of elementary school students, which is shown through the results of the t-test with a significance value of $p < 0.001$ and the acquisition of an N-Gain value of 0.57 in the medium category. The novelty of this research lies in the integration of student worksheets systematically compiled with comic-based visual narratives within a concise, structured microlearning framework to optimize the development of numeracy skills while simultaneously strengthening learning motivation. This approach contributes to the development of innovative learning designs that integrate cognitive and affective aspects, as well as to improvements in conventional learning practices that tend to separate the two.nThis study still has limitations in the scope of participants, which is not yet extensive, and the research context is limited to one school environment, so generalization of the findings to more diverse contexts needs to be done carefully. In addition, the relatively short duration of the intervention did not fully demonstrate the sustainability of improvements in numeracy skills and learning motivation in the long term. Therefore, further research is recommended to include more heterogeneous participants, employ a longitudinal design, and examine additional variables, such as learning independence and critical thinking skills. From a methodological perspective, it is also recommended that the study use MANOVA as the primary analytical technique when involving more than one variable. If the results of the MANOVA test indicate significance, the analysis can proceed with a univariate ANOVA test, thereby eliminating the need for separate t-tests. This approach is considered more appropriate for providing a more comprehensive understanding of the relationships among variables. The findings of this study imply that the integration of comic-based microlearning with student worksheets has the potential to be an effective and innovative learning strategy, so that teachers are expected to adapt this approach in learning practices. At the same time, curriculum developers and education policymakers can consider its implementation as part of a more adaptive, contextual, and sustainable learning design.

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