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Evaluation of the Effectiveness of Interactive Student Worksheets (LKS) in Improving Mathematics Learning Outcomes in Elementary School Students

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Abstract

The limited number of studies on the use of interactive student worksheets (*Lembar Kerja Siswa*, LKS) in *Madrasah Ibtidaiyah* (Islamic elementary schools) forms the background of this research, despite the widely held belief that interactive learning materials hold significant potential for improving students' mathematical understanding. This study aims to analyze the influence of interactive LKS utilization on the mathematics learning outcomes of fourth-grade students at MI Muhammadiyah Jimbung, Klaten Regency. A quantitative approach with a correlational design was employed, using total population sampling (N = 45). Data were collected through a 24-item Likert scale questionnaire measuring the intensity of LKS use, documentation of daily test scores as indicators of learning outcomes, and contextual classroom observations. Data analysis included descriptive statistics, assumption tests (normality and linearity), and simple linear regression using SPSS. The results show a positive and significant influence of interactive LKS use on mathematics learning outcomes ($R = 0.450$; $R^2 = 0.202$; $B \approx 0.383$; $F(1,43) = 10.889$; $p = 0.002$). This indicates that 20.2% of the variation in mathematics learning outcomes can be explained by the intensity of interactive LKS utilization. These findings reinforce the role of interactive LKS as a key component in foundational mathematics instruction, particularly within the context of the *Kurikulum Merdeka*, and support the application of multimodal

learning and scaffolding principles in the classroom. The study's implications highlight the need to improve LKS design quality, provide teacher training in the development of interactive teaching materials, and encourage further experimental research using standardized test instruments to strengthen causal validity and generalizability.

Keywords: Interactive Student Worksheet; Mathematics Learning Outcomes; *Madrasah Ibtidaiyah*; *Kurikulum Merdeka*; Mathematics Instruction

INTRODUCTION

Education is a fundamental human need and functions to optimally develop students' potential both intellectually and spiritually (Lubis & Albina, 2024). The teaching–learning process plays a crucial role in forming students' character, skills, and critical thinking abilities. According to Law Number 20 of 2003 on the National Education System, education must create an active, creative, and enjoyable learning environment so that students can develop their potential to the fullest. Teachers are required to manage effective and innovative learning so that students learn actively and meaningfully.

Advances in information and communication technology have brought significant changes to education. Traditional teacher-centered instruction has been transformed into student-centered learning. Integrating technology into education enables the creation of more interactive and engaging learning environments, increasing student motivation and participation (Guaña-Moya et al., 2024; Kuznetsov, 2025). Instructional materials such as Student Worksheets (LKS) have evolved into interactive learning media that function not only as learning aids but also as tools for student exploration and self-reflection on learned concepts.

Mathematics is often perceived as difficult and boring by many elementary school students. This perception stems from the abstract nature of mathematical content and instructional methods that are insufficiently contextual (Jalal, 2022; Oktavia & Hidayati, 2022). Therefore, teachers need to use concrete and interactive instructional materials to help students grasp mathematical concepts more easily. One effective solution is the use of interactive Student Worksheets (LKS), which can stimulate student engagement, collaboration, and critical thinking (Marzuki & Silvia, 2023; Silitonga & Purba, 2024).

International studies illustrate serious challenges in students' mathematical literacy. According to the Programme for International Student Assessment (PISA) 2018 report by the OECD (2019), Indonesia's mathematics score was 379 compared with the OECD average of 489, with about 71% of students not reaching the minimum competency. Meanwhile, the Trends in International Mathematics and Science Study (TIMSS) categorizes students' mathematical literacy into four reference levels: advanced, high, intermediate, and low (Munaji & Setiawahyu, 2020). Indonesia ranked 44th out of 49 participants, with fourth-grade students scoring 397 compared to the international average of 500 (Mullis et al., 2012). These results place Indonesian students in a low-standard category and highlight an urgent need to improve mathematical literacy (Amaliya et al., 2024). This situation is consistent with findings from the Ministry of Education, Culture, Research, and Technology in 2022: the average mathematical competence of Indonesian students remains relatively low, as the 2022 National Assessment results showed that fewer than 50% of elementary students reached the minimum numeracy competency (Amaliya et al., 2024). This context has prompted the Kurikulum Merdeka (Independent Curriculum) policy, which grants educators freedom to design teaching methods and materials tailored to students' needs (Manalu et al., 2025) and is expected to bring substantive changes to mathematics instruction.

The integration of digital technology into education is recognized for its potential to create more active and engaging learning experiences (Fajriati et al., 2024; Wahyudi & Jatun, 2024). Narvaez Rojas et al. (2021) note that interactive instructional media can increase student engagement in the learning process. Purwanto (2022) also emphasizes the importance of student-centered interactive media. Therefore, teachers are encouraged to use interactive media such as videos, animated graphics, or digital worksheets to overcome the limitations of traditional teacher-centered models. Several studies indicate that interactive media are effective in elementary contexts. For example, Amaliya et al. (2024) found that interactive digital LKS increased mathematical literacy among primary school students (N-gain = 0.83). Sari et al. (2022) reported that HOTS-based interactive LKS were highly valid, practical, and effective (N-gain = 0.70) for science learning in elementary schools. Similarly, Novaliyosi et al. (2022) developed interactive LKS that were valid and practical for fostering higher-order thinking skills. These findings underscore the need for learning media that actively engage students to improve mathematics instructional effectiveness.

Responding to these issues, this study developed interactive LKS based on the Kurikulum Merdeka as an innovative mathematics instructional medium for fourth-grade classes. The interactive media were designed to increase student engagement. Bitu et al. (2024) and Aulia et al. (2024) emphasize that interactive learning media can enhance student involvement, while Nurhalimah & Azzahra (2023) stress the need for media that actively engages students in constructing understanding. Sari et al. (2022) also report that HOTS-based interactive LKS they developed were very valid and practical. Therefore, this study responds by designing interactive LKS that integrate contextual elements and problem-solving activities tailored to students' needs.

This research aligns with the spirit of the Kurikulum Merdeka, which encourages teacher innovation. Manalu et al. (2025) report that implementing the Kurikulum Merdeka in elementary mathematics instruction increases student engagement and contextual understanding. Likewise, Solehah & Setiawan (2023) argue that the Kurikulum Merdeka is expected to bring major changes to mathematics teaching through teacher-driven innovation. Consequently, this study focuses on developing interactive LKS consistent with the principles of the Kurikulum Merdeka and is expected to facilitate more active and meaningful mathematics learning at MI Muhammadiyah Jimbung.

Several previous studies have examined the development of interactive Student Worksheets (LKS) or similar digital instructional media. Sari et al. (2022) developed HOTS-based interactive LKS for elementary school students and reported that the product was valid, practical, and effective (N-gain = 0.70) in science instruction. Novaliyosi et al. (2022) likewise designed HOTS-oriented interactive LKS that demonstrated very good validity and practicality. At the junior high level, Sampoerno et al. (2023) successfully developed interactive LKS based on Realistic Mathematics Education (RME) for the topic of two-variable linear equations, achieving a validity score of 94.47% (very feasible). Arsyad et al. (2023) found that the use of LKS within a problem-based learning strategy improved mathematics learning outcomes in junior high schools. In addition, Amaliya et al. (2024) showed that interactive digital LKS can significantly enhance mathematical literacy among fourth-grade elementary students.

Despite the promising results reported by these studies, important gaps remain. Most previous research was conducted in regular public schools (elementary and junior high) or addressed different subject matter, whereas the context of Madrasah Ibtidaiyah

(MI) Muhammadiyah Jimbung has been little explored. Moreover, few studies have specifically developed interactive LKS tailored to the Independent Curriculum (Kurikulum Merdeka) and to the "Profil Pelajar Pancasila" (Pancasila Student Profile). Therefore, this study aims to fill that gap by examining interactive mathematics LKS in MI Muhammadiyah Jimbung, Klaten.

The novelty of this research lies in the development of interactive LKS for fractions targeted at fourth-grade students at MI Muhammadiyah Jimbung within the framework of the Independent Curriculum. The instructional media were designed in accordance with Phase B of the Independent Curriculum, thereby supporting student engagement and the development of the Pancasila Student Profile. The application of the Realistic Mathematics Education (RME) approach is also a distinguishing feature, making the developed interactive LKS a valid and usable product. These worksheets are designed to facilitate contextual problem solving and hands-on activities aligned with the characteristics of contemporary curriculum approaches.

From a theoretical perspective, the design of these interactive LKS is grounded in cognitive developmental theories by Jean Piaget and Jerome Bruner. Bruner (2017) emphasizes that children build understanding through enactive, iconic, and symbolic representations in sequence. Consequently, the interactive LKS are organized progressively (manipulative → visual → conceptual) to match students' developmental stages. This constructivist orientation ensures that learners actively construct mathematical concepts through guided experiences. In addition, multimedia learning theory supports the combined use of text and graphics in digital worksheets to optimize learning. On this theoretical basis, the interactive LKS are expected to enhance students' conceptual understanding and mathematical thinking.

This study focuses on the effect of using interactive LKS aligned with the Independent Curriculum on the mathematics learning outcomes of fourth-grade students at MI Muhammadiyah Jimbung, Klaten, for the 2025/2026 academic year. Specifically, the study aims to analyze whether interactive LKS can improve students' understanding of fractions and their mathematics achievement. The problem statement is described descriptively: how do mathematics learning outcomes differ between students who use interactive LKS and those who use conventional LKS, and how do students respond to the implementation of interactive LKS? Ultimately, this study is expected to provide empirical

evidence regarding the effectiveness of interactive LKS in mathematics instruction at MI Muhammadiyah Jimbung.

METHODS

This study employed a quantitative approach with a correlational design because the primary objective was to determine whether—and to what extent—there is a relationship and influence between the use of interactive Student Worksheets (LKS) as the independent variable and mathematics learning outcomes as the dependent variable. The quantitative approach was selected because it emphasizes numerical measurement, hypothesis testing, and statistical analysis that enable the researcher to draw generalizable conclusions from numeric data (Creswell, 2014).

The implemented design was correlational and non-experimental, meaning the study was observational and did not manipulate treatments on subjects. This design was chosen because the researcher intended to observe the effect of interactive LKS as they were implemented in the field on student outcomes in a natural setting, rather than through randomized intervention or experimental grouping. A correlational design allows assessment of the degree of association (correlation) and simple prediction (regression) between available variables. This design differs from R&D or pre-experimental designs commonly used in product development studies (which focus on validity/practicality), as the present study concentrates on empirical evidence of influence in the context of MI Muhammadiyah Jimbung. The distinctiveness of this study lies in its quantitative examination of interactive LKS within the Independent Curriculum at the madrasah level, thereby enriching literature that has largely focused on public schools or different grade levels and topics.

The study population consisted of all fourth-grade students at MI Muhammadiyah Jimbung for the 2025/2026 academic year, totaling 45 students. The study employed saturated sampling so that the entire population served as the sample, excluding only students who did not meet inclusion criteria (e.g., prolonged absence during data collection). Consequently, the analyzed sample comprised 45 students as recorded in the final data processing. Saturated sampling was chosen because the population is relatively small and the study aims to obtain a representative picture of the entire target group; methodologically, this technique is recommended in educational research when the

population is small and all members can be included without introducing selection bias (Sugiyono, 2019). Inclusion criteria included formal enrollment in fourth grade and active participation during the data collection period (August–October 2025), whereas extended absenteeism constituted grounds for exclusion.

Data were collected using complementary instruments: a questionnaire measuring interactive LKS usage, documentation of daily mathematics test scores as an indicator of learning outcomes, and field observations as contextual data. The questionnaire was developed according to a rubric of interactive LKS indicators (visual design, ease of use, content quality, student engagement, and instructional benefit) and comprised 24 items on a four-point Likert scale; daily test scores were obtained from teacher records corresponding to relevant thematic units; observation was used to document usage frequency and how LKS were implemented in the classroom. Field procedures included coordination and authorization from the madrasah, guided administration of the questionnaire by the researcher, and collection of score documentation; all data collection took place between August and October 2025.

To ensure instrument quality, systematic validity and reliability procedures were undertaken. Content validity of the questionnaire was evaluated by experts using Aiken's V to assess each item's alignment with the indicators; items that met the Aiken's V threshold proceeded to pilot testing. Internal reliability was then estimated using Cronbach's alpha on pilot data prior to the main data collection; interpretations of reliability followed standard guidelines ($\alpha \geq 0.70$ considered acceptable for basic research) (Aiken, 1985; Nurjanah et al., 2023; Tavakol & Dennick, 2011).

Data analysis comprised descriptive and inferential stages carried out with IBM SPSS Statistics v22 and Microsoft Excel 2019. Initial analyses included descriptive statistics (mean, median, mode, standard deviation, minimum and maximum values) to describe the characteristics of LKS usage scores and learning outcomes. Next, parametric prerequisites were tested (normality via Shapiro–Wilk or Lilliefors as appropriate for sample size), linearity of the relationship between variables, and homogeneity of variance where applicable. After prerequisites were satisfied, hypothesis testing used simple linear regression to determine whether interactive LKS usage significantly influenced mathematics learning outcomes, including an evaluation of the independent variable's contribution to variance in the dependent variable (coefficient of determination, R^2). These

procedures align with common quantitative practices in correlational studies; if supporting qualitative data (e.g., observation themes) were to be analyzed further, thematic analysis or display-matrix techniques as recommended by Miles, Huberman, and Saldaña (2014) could enrich interpretation.

Ethical and administrative procedures were followed before and during the study: the researcher obtained formal permission from the madrasah, protected participant confidentiality using coded identifiers, used data solely for academic purposes, and securely stored documents and datasets; relevant permission letters and consent forms were documented. In addition, scheduling, data collection flow, and coordination mechanisms with teachers and the headmaster were designed to minimize disruption to instructional time and to ensure the completeness and validity of the data. With this methodological framework, the study is expected to provide empirically sound and accountable evidence regarding the influence of interactive LKS on fourth-grade students' mathematics learning outcomes at MI Muhammadiyah Jimbung.

RESULTS

Description of Questionnaire Data on the Use of Interactive Student Worksheets (LKS) in Fourth-Grade Mathematics at MI Muhammadiyah Jimbung

In this study, the researcher used a questionnaire administered to 45 students as respondents. The instrument aimed to obtain data on the effect of using Interactive Student Worksheets (LKS) on mathematics learning outcomes. The questionnaire consisted of 24 statements with four response options: strongly agree, agree, disagree, and strongly disagree. All questionnaires were distributed to fourth-grade students at MI Muhammadiyah Jimbung as the study subjects. The completed questionnaires were then processed and presented in a frequency distribution table to facilitate analysis. The frequency distribution table was prepared through the following steps:

a. **Identify the highest and lowest observed scores.** The highest score was 89 and the lowest was 63.

b.**Determine the range.**

Range = Largest Value – Smallest Value
= 89 – 63
= 26

c.**Determine the number of classes (K).**

K = 1 + (3.33 log n)
= 1 + (3.33 log 45)
= 1 + (3.33 × 1.6)
= 6.455, rounded to 7

d.**Determine the class interval width (i).**

I = Range / K
= 26 / 7
= 3.714, rounded to 4

The resulting frequency distribution is shown in Table 1 below:

Table 1. Cumulative Frequency Distribution

Class No.	Interval	Frequency	Cumulative Frequency
1	63-66	3	3
2	67-70	6	9
3	71-74	6	15
4	75-78	12	27
5	79-82	7	34
6	83-86	8	42
7	87-90	3	45

The mean score for interactive LKS use was 76.93 (N = 45), with a standard deviation (SD) of 6.517 (variance ≈ 42.48) and a mean standard error ≈ 0.97. The frequency distribution by category shows that 20.0% of respondents fell into the **low** category (63–70), 40.0% into **moderate** (71–77), 33.3% into **high** (78–84), and 6.7% into **very high** (85–91). The descriptive statistics for the LKS-use scores are presented in Table 2.

Table 2. Descriptive Statistics for Variable X

N	**Valid**	**45**
	Missing	0
Mean		76,93
Standard Error		0,97
Median		78,00
Mode		78,00
Standard Deviation		6,517
Sample Variance		42
Range		26
Minimum		63
Maximum		89
Sum		3462

The categorized results for the LKS-use variable are as follows: interval 63–70 with a frequency of 9 (20%); interval 71–77 with a frequency of 12 (26%); interval 78–84 with a frequency of 20 (44%); and interval 85–91 with a frequency of 4 (8%). Table 3 presents these categories.

Table 3. Categorized Questionnaire Data on Interactive LKS Use

		Interval	**Frequency**	**Percent**
Valid	**Low**	63 – 70	9	20
	Moderate	71 – 77	12	26
	High	78 – 84	20	44
	Very High	85 - 91	4	8
	Total		**45**	**100**

Table 3 is depicted in the histogram in Figure 1 below.

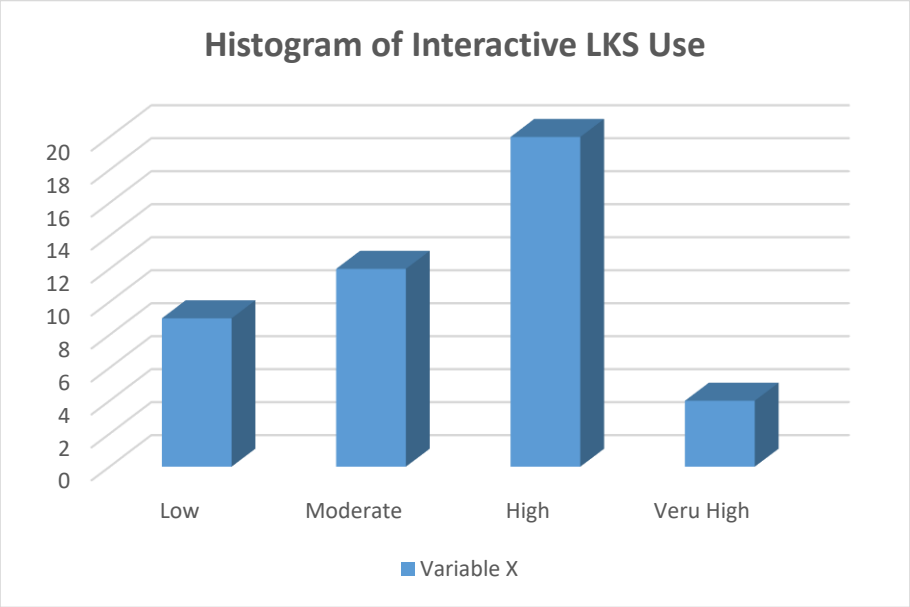

Figure 1. Histogram of Interactive LKS Use

Based on the study data presented, the use of Interactive LKS in fourth-grade mathematics at MI Muhammadiyah Jimbung is classified as **high**, with a mean score of 76.93. This finding indicates that Interactive LKS, as an instructional resource, can increase motivation and support students' achievement.

Students' Mathematics Learning Outcomes in Fourth Grade at MI Muhammadiyah Jimbung

Student learning outcomes serve as an indicator of achievement and the attainment of instructional goals. Based on the research data and the daily test scores of 45 students, the highest score was 91, the lowest was 74, the mean was 81.29, and the standard deviation (SD) was 5.546. A summary of these calculations is presented in Table 4 (SPSS v22 output).

Table 4. Descriptive Statistics of Students' Mathematics Learning Outcomes

	N	Range	Min	Max	Sum	Mean	Std. Deviation
Learning Outcomes	45	17	74	91	3658	81.29	5,546
Valid N (listwise)	45						

The categorized results for mathematics learning outcomes are as follows: interval 60–76 with a frequency of 5 (11.1%); interval 76–81 with a frequency of 21 (46.7%); interval 81–86 with a frequency of 6 (13.3%); and interval 86–92 with a frequency of 13 (28.9%). Table 5 presents these categories.

Table 5. Categorization of Students' Mathematics Learning Outcomes

		Interval	Frequency	Percent
Valid	**Low**	70 - 76	5	11.1
	Moderate	76 - 81	21	46.7
	High	81 - 86	6	13.3
	Very High	86 - 92	13	28.9
	Total		**45**	**100.0**

According to the SPSS v22 results, the variable of mathematics learning outcomes is visualized in the histogram in Figure 2 below.

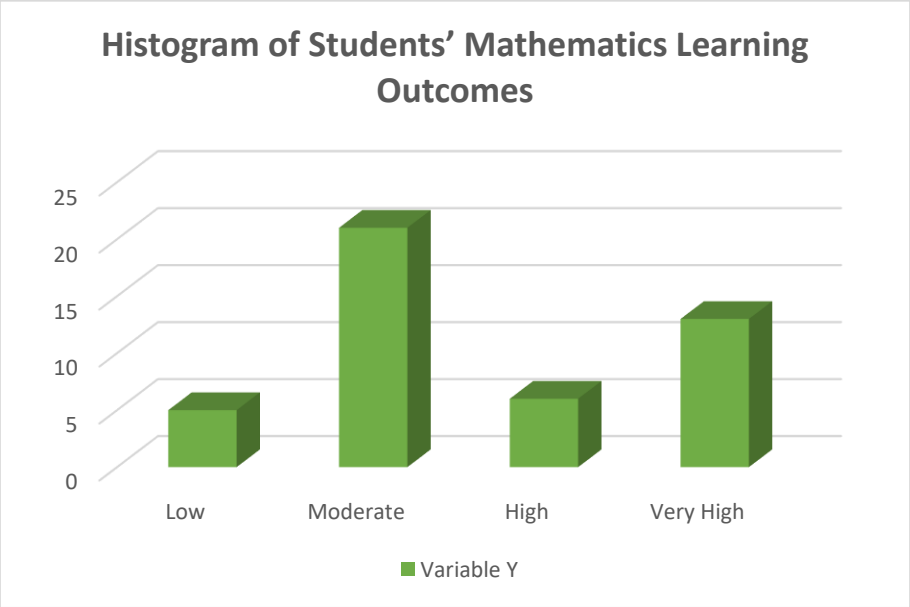

Figure 2. Histogram of Students' Mathematics Learning Outcomes

Based on the data presented, it can be concluded that the mathematics learning outcomes of fourth-grade students using Interactive LKS at MI Muhammadiyah Jimbung fall into the **moderate** category. The mean score was 81.29, with a score range of 74 to 91. This finding suggests that most students achieved satisfactory outcomes after using Interactive LKS in instruction.

Assumption Checks

Normality Test

The normality test was conducted to determine whether the data were normally distributed and followed the standard normal pattern. In this study, the Shapiro–Wilk test was used (N = 45), with data considered normal if the significance value (α) > 0.05. The results are shown in Table 7.

Table 7. Normality Test Results

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Interactive LKS Use	.126	45	.069	.970	45	.283
Mathematics Learning Outcomes	.085	45	.200*	.979	45	.580
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						

Normality was tested using Shapiro–Wilk because the sample size (N = 45) is below 50. The significance values (Sig.) were 0.283 for Interactive LKS Use (X) and 0.580 for Mathematics Learning Outcomes (Y). Since both Sig. values are > 0.05, both variables can be assumed to be normally distributed, and the parametric assumptions are satisfied. Analysis therefore proceeded to the linearity test.

Linearity Test

The linearity test examines whether the relationship between the two variables is linear and not significantly deviated. This test is a prerequisite for linear regression analysis. In this study, the linearity test used a significance level of 0.05. The results are presented in Table 8.

Table 8. Linearity Test Results

ANOVA Table							
			Sum of Squares	df	Mean Square	F	Sig.
Learning Outcomes * LKS Use	Between Groups	(Combined)	604.800	20	30.240	.898	.593
		Linearity	15.501	1	15.501	.460	.504
		Deviation from Linearity	589.299	19	31.016	.921	.567
	Within Groups		808.000	24	33.667		
	Total		1412.800	44			

Based on Table 8, the Deviation from Linearity has a Sig. value of 0.567 > 0.05, indicating a linear relationship between the independent and dependent variables. Thus, there is a statistically acceptable linear relationship between Interactive LKS Use (X) and Mathematics Learning Outcomes (Y).

Hypothesis Testing

Hypothesis testing was conducted to determine the extent to which Interactive LKS Use influences students' Mathematics Learning Outcomes. Simple linear regression was used, with decisions based on comparing Sig. values to $\alpha = 0.05$ and by examining the coefficient of determination (R Square):

a. If Sig. < 0.05, variable X influences variable Y.

b. If Sig. > 0.05, variable X does not influence variable Y.

Table 9. Simple Linear Regression

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28.543	1	28.543	10.889	.002[b]
	Residual	112.714	43	2.621		

	Total	141.258	44			
a. Dependent Variable: Y2						
b. Predictors: (Constant), X2						

Table 10. Simple Linear Regression

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.450[a]	.202	.184	1.619
a. Predictors: (Constant), X2				

From Tables 9 and 10:

a. The calculated F = 10.889 with Sig. = 0.002 < 0.05 indicates a significant effect of the independent variable on the dependent variable. The hypothesis test concludes: **H_1 accepted, H_0 rejected**—there is an effect of Interactive LKS Use on fourth-grade students' mathematics learning outcomes at MI Muhammadiyah Jimbung.

b. The correlation is R = 0.450, and the coefficient of determination (R Square) is 0.202, which means Interactive LKS Use accounts for **20.2%** of the variance in mathematics learning outcomes.

c. Simple linear regression shows a significant effect of Interactive LKS Use on mathematics learning outcomes. The correlation (R = 0.450) indicates a moderate positive relationship. The coefficient of determination (R^2 = 0.202) indicates that about 20.2% of the variance in outcomes can be explained by variation in LKS use, while 79.8% is influenced by other factors (e.g., instructional methods, home support, learning motivation). The ANOVA result F(1,43) = 10.889 with p = 0.002 confirms statistical significance at α = 0.05.

d. The estimated regression coefficients indicate a slope (B) = **0.383** with standard error SE(B) = **0.1159**, yielding **t = 3.304** (df = 43). The intercept (a) = **51.8295** with an approximate standard error of **8.947**. The standard error of estimate (s_e) = **5.01**. The

overall regression p-value ($p = 0.002$) has been reported above, and the significant B coefficient supports the conclusion that Interactive LKS Use contributes meaningfully to variation in mathematics learning outcomes.

DISCUSSION

Analysis of Findings

The results show a positive and significant effect of interactive LKS (Interactive Student Worksheets) on fourth-grade students' mathematics learning outcomes at MI Muhammadiyah Jimbung. Simple linear regression produced $R = 0.450$, $R^2 = 0.202$, slope $B \approx 0.383$, and $F(1,43) = 10.889$ with $p = 0.002$. Practically, this means that higher interactive LKS-use scores are associated with higher achievement scores (approximately a 0.38-point increase in learning outcomes for every 1-point increase in the LKS score) and LKS use accounts for about 20.2% of the variance in students' outcomes; the remaining ≈79.8% is influenced by other factors. This interpretation indicates a meaningful, though not exhaustive, effect interactive LKS are one among several contributors to mathematics achievement.

The positive effect of interactive LKS aligns with constructivist premises that learning opportunities for exploration, multimodal representation, and authentic tasks facilitate students' knowledge construction (Bruner, 2017). Interactive LKS that integrate visual elements, contextual activities, and quizzes/feedback allow students to practice fraction concepts progressively (enactive → iconic → symbolic), easing the transition from manipulation to abstraction. However, the moderate effect size ($R = 0.450$; $R^2 = 0.202$) indicates that although LKS support cognitive and motivational processes, successful learning also depends on implementation quality (e.g., how teachers facilitate use), learner readiness, and environmental factors (motivation, parental support). This finding carries a practical message: LKS development should be accompanied by capacity-building for teachers to facilitate LKS activities so their potential is fully realized.

Comparison with Previous Studies

Your results are consistent with studies showing that interactive LKS/LKPD improve engagement and academic performance. For example, Amaliya et al. (2024) reported gains in mathematical literacy following a digital LKS intervention, and Sari et al.

(2022) found HOTS-based LKS effective in elementary contexts. These convergent findings support the claim that interactivity (immediate feedback, visuals, contextual problems) contributes to conceptual understanding. The difference lies in effect magnitude: several R&D studies report large N-gain values under product-trial conditions, whereas correlational field studies like yours tend to show moderate contributions because real-world settings include uncontrolled confounders (e.g., instructional variation, classroom conditions).

Theoretically, interactive LKS operate along three primary pathways: cognitive (presenting representations that facilitate schemata and dual processing), motivational (increasing interest and persistence through appealing design and feedback), and social (promoting collaboration in task completion). Multimedia approaches and instructional designs that provide scaffolding aligned with cognitive developmental stages enhance task engagement and deep processing (Narvaez Rojas et al., 2021; Purwanto, 2022). In addition, graduated practice and rapid feedback approximate behaviorist reinforcement and repetition principles that support automatization of numerical skills. This combination of mechanisms plausibly explains the positive effects observed in this study.

Research Implications

These findings add empirical evidence that interactive learning media can serve as an important mediating variable between autonomy-oriented curriculum policy (Kurikulum Merdeka) and concrete learning outcomes. The results support integrating constructivist theory and multimedia learning approaches in instructional material development. Practically, the implications are: (1) teachers and curriculum developers should embed interactivity, feedback, and differentiated difficulty into LKS; (2) teacher training on LKS use and facilitation strategies (scaffolding, questioning, differentiation) should be integral to implementation; and (3) schools may position interactive LKS as part of a media portfolio supporting independent learning, accompanied by quality monitoring of implementation.

Research Limitations

This study has several limitations. First, the non-experimental correlational design constrains strong causal inference between LKS use and outcomes unmeasured variables (e.g., prior ability, instructional quality, home support) may also influence results. Second, the sample size (n = 45) and single-site context (MI Muhammadiyah Jimbung) limit generalizability; local characteristics of the madrasah and teachers may differ from other

schools. Third, LKS-use measurement relies on self-report questionnaires and daily test records, which are practical but may be less standardized than formal testing instruments, introducing possible measurement bias. Fourth, the focus on fractions limits transferability to other mathematics topics. Recognizing these limitations ensures fair interpretation and guards against overclaiming.

CONCLUSION

This study concludes that the use of interactive Student Worksheets (LKS) has a positive and significant effect on fourth-grade students' mathematics learning outcomes at MI Muhammadiyah Jimbung. Simple linear regression produced $R = 0.450$ and $R^2 = 0.202$, indicating that about 20.2% of the variance in outcomes is explained by variation in LKS use. The regression slope ($B \approx 0.383$) suggests that each 1-point increase in LKS-use score is associated with an average increase of about 0.38 points in achievement; $F(1,43) = 10.889$ with $p = 0.002$ confirms statistical significance at $\alpha = 0.05$. These results address the study objective by showing that interactive LKS contribute to improved mathematics outcomes in the research context.

The findings indicate that interactive LKS function as an effective medium for facilitating conceptual understanding in elementary mathematics through structured activities, feedback, and representations that support thinking processes. Nevertheless, the moderate effect size suggests LKS should be viewed as part of a broader learning ecosystem rather than a stand-alone solution; other factors such as teacher facilitation quality, student readiness, and environmental support also shape achievement.

This study offers twofold contributions: first, it provides quantitative empirical evidence on the direction and magnitude of interactive LKS effects on mathematics outcomes at the Madrasah Ibtidaiyah level, extending understanding of interactive materials' effectiveness in a specific context; second, it presents a practical measurement model combining an LKS-use questionnaire with empirical processing of daily test scores, which can serve as a reference point for subsequent studies and for efforts to improve instructional materials in the field.

Based on the design and findings, several next steps are recommended. To strengthen causal evidence, future work should employ experimental or quasi-experimental designs (e.g., treatment–control groups) with larger samples across multiple schools to

enhance generalizability. Subsequent studies should incorporate standardized pretest–posttest measures to capture ability change more sensitively and include key control variables (e.g., prior ability, instructional quality, family support). Longitudinal designs can help assess the stability of LKS effects over time. For practice, schools are encouraged to integrate interactive LKS into lesson planning with attention to pedagogy: graduated task design, scaffolding, and formative feedback mechanisms. Schools should also provide teacher training and mentoring to ensure pedagogically consistent use, and adopt implementation-monitoring tools (observations, fidelity rubrics) to safeguard quality. With stronger design, facilitation, and rigorous follow-up research, interactive LKS can become a key component in improving mathematics literacy and outcomes at the elementary level.

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