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Culturally responsive teaching assisted by interactive media: Effects on learning activity and mathematics achievement

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Abstract. Low mathematics learning activity and achievement remain challenges in primary education. Preliminary assessment showed that only 2 of 14 third-grade students (14.3%) achieved the minimum mastery criterion (KKM = 70), with a mean pretest score of 43.50. However, limited evidence has examined the integrated use of Culturally Responsive Teaching (CRT) and interactive media while simultaneously evaluating learning activity and mathematics achievement through MANOVA. This study examined their effects on both outcomes. A quantitative quasi-experimental nonequivalent control group design involved 28 third-grade students, with 14 students each in the experimental and control groups. Data were collected using a learning activity observation sheet and mathematics achievement test and analyzed using descriptive statistics, Shapiro–Wilk, Levene's test, independent-samples *t*-tests, and MANOVA. The results showed significant differences in learning activity ($t(26) = 5.92$, $p < .001$) and mathematics achievement ($t(26) = 3.85$, $p = .001$), favoring the experimental group. MANOVA confirmed a significant simultaneous effect (Pillai's Trace = .63, $F(2, 25) = 21.75$, $p < .001$, partial $\eta^2 = .63$). The study provides a multivariate perspective on both outcomes and a practical instructional alternative for elementary mathematics teachers. Future research should involve larger samples, multiple schools, and longer interventions.

Introduction

Mathematics is a fundamental competency for developing logical reasoning, problem solving, and informed decision-making in primary education. However, mathematics learning in many contexts continues to face challenges in translating formal concepts into meaningful learning experiences. In Indonesia, the 2022 Programme for International Student Assessment results showed that Indonesian students' mathematics performance remained substantially below the OECD average, indicating persistent difficulties in applying mathematical knowledge to real-world situations (OECD, 2023). At the classroom level, meaningful mathematics learning also depends on students' active participation because learning mathematics requires students to communicate ideas, ask questions, discuss strategies, and apply concepts when solving problems (Timmerman, 2023). Thus, mathematics achievement should not be viewed only as the final test score but also in relation to students' engagement in the learning process. In this study, learning activity refers to students' observable participation during mathematics instruction, including participation, collaboration, questioning, problem solving, and task completion, whereas mathematics achievement refers to students' mastery of mathematical concepts and ability to solve mathematical problems as measured through an achievement test. These two outcomes provide complementary information about both the learning process and the learning result (Falloon & G., 2023; Robson & LeVoguer, 2024; Decristan et al., 2023; Widana et al., 2024).

The urgency of addressing these issues was evident in the research setting. Preliminary observation at SDN 2 Ngraho showed that only 2 of 14 third-grade students (14.3%) achieved the minimum mastery criterion (KKM = 70), while the mean pretest score was only 43.50. Most students remained dependent on teacher explanations, showed limited participation during classroom activities, and experienced difficulties connecting mathematical concepts with situations in their daily lives. These conditions indicate that the problem is not limited to low mathematics achievement but also concerns the learning activity through which mathematical understanding is developed. Conventional instruction that primarily positions students as recipients of explanations may provide insufficient opportunities for students to connect mathematical ideas with their own experiences. Therefore, an instructional approach is needed that can increase students' participation while making mathematical concepts more relevant to their everyday and cultural contexts. This need is particularly important in primary classrooms, where students' prior experiences and familiar environments can serve as meaningful resources for constructing mathematical understanding (Nurhasanah et al., 2024; Tran et al., 2023; Nolan & Xenofontos, 2023; Ariyanti et al., 2025; Jaya et al., 2025).

Culturally Responsive Teaching (CRT) provides a relevant pedagogical framework for addressing this challenge because it connects classroom learning with students' cultural backgrounds, experiences, knowledge, and everyday contexts. In mathematics education, culturally responsive practices can help students recognize mathematical ideas in familiar activities and cultural practices, making abstract concepts more meaningful and accessible. This approach is particularly relevant to Indonesian primary classrooms because students learn within diverse cultural, linguistic, geographical, and community contexts. Integrating local experiences into mathematics instruction can therefore provide bridges between formal mathematical representations and knowledge that students already possess (Suh & Park, 2023). Research has shown that culturally responsive perspectives can support meaningful mathematics learning and encourage teachers to consider students' cultural experiences when designing instruction (Nolan & Xenofontos, 2023). Recent research also indicates that CRT can contribute to engagement and learning in elementary mathematics by making instruction more contextualized and responsive to students' experiences (Li et al., 2021; Ntumi, 2021; Shultz et al., 2024).

Nevertheless, CRT alone does not necessarily address the need for engaging learning environments supported by appropriate instructional media. Interactive media can complement culturally responsive pedagogy by providing visual, interactive, and contextual representations that allow students to explore mathematical ideas more actively. Previous studies have reported benefits of interactive and technology-supported learning for student engagement and conceptual understanding, while culturally responsive approaches have been examined primarily in relation to meaningful learning, achievement, or teachers' pedagogical practices (Fatoni & Bektiningsih, 2024; Widana & Laksitasari, 2023). Recent empirical studies in Indonesian elementary mathematics have also examined CRT in relation to mathematics achievement, including CRT supported by learning media, but these studies have generally focused on a single primary outcome or used classroom action research designs. These limitations leave an important gap: limited evidence has examined the integrated use of CRT assisted by interactive media while simultaneously evaluating students' learning activity and mathematics achievement within a single experimental framework.

Examining the two outcomes simultaneously provides both theoretical and methodological value. Theoretically, learning activity represents the behavioral dimension of students' engagement during instruction, whereas mathematics achievement represents the cognitive outcome of learning. An instructional intervention that improves achievement but does not encourage active participation may provide only a partial picture of its educational effectiveness. Conversely, increased participation without corresponding improvement in mathematical understanding may not indicate sufficient instructional impact. Methodologically, MANOVA allows the two related dependent variables to be examined simultaneously rather than through separate analyses alone, providing evidence of whether the instructional treatment produces a combined multivariate effect (Ntumi, 2021). The present study therefore extends previous research by connecting culturally responsive pedagogy, interactive media, learning activity, and mathematics achievement within one analytical framework. This distinction is important because previous studies have commonly examined CRT or interactive media separately, emphasized one outcome, or relied on univariate analyses.

Based on this gap, the present study examined the effects of Culturally Responsive Teaching assisted by interactive media on third-grade students' learning activity and mathematics achievement in primary mathematics learning. Specifically, the study investigated whether the instructional treatment produced significant effects on learning activity, significant effects on mathematics achievement, and a significant simultaneous effect on both outcomes. The study was guided by three hypotheses: (H1) Culturally Responsive Teaching assisted by interactive media significantly affects students' learning activity; (H2) it significantly affects students' mathematics achievement; and (H3) it significantly affects learning activity and mathematics achievement simultaneously. By examining these outcomes within the same instructional and multivariate framework, the study seeks to provide more comprehensive evidence on how culturally responsive, technology-supported mathematics instruction can address both students' participation and achievement.

Method

Research Method and Design

A quantitative quasi-experimental approach was employed to examine the effects of Culturally Responsive Teaching (CRT) assisted by interactive media on students' learning activity and mathematics achievement. Numerical data were collected from classroom observations and mathematics achievement tests and subsequently analyzed using inferential statistical procedures (Creswell & Creswell, 2023). A Nonequivalent Control Group Design was selected because the students were already organized into intact classes before the research was conducted. Individual random assignment was not feasible without changing the existing classroom structure. Class III A was designated as the experimental group and Class III B as the control group, with 14 students in each class. Both groups completed a pretest before the intervention and a posttest after the intervention. Mathematics instruction in the experimental group employed CRT assisted by interactive media, whereas the control group received conventional mathematics instruction (Psyllou et al., 2023).

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Participants and Sampling Technique

The research involved 28 third-grade students from two parallel classes at SDN 2 Ngraho, Ngraho District, Blora Regency, Central Java. Class III A consisted of 14 students and served as the experimental group, while Class III B consisted of 14 students and served as the control group. Purposive sampling was used because the existing classroom organization had been established before the research and individual random assignment was not feasible.

Table 2. Distribution of Research Participants

Group	Class	Students	Treatment
Experimental	III A	14	CRT assisted by interactive media
Control	III B	14	Conventional mathematics instruction
Total		**28**	

Research Setting and Timeline

Research activities were conducted at SDN 2 Ngraho, Blora Regency, Central Java, during April–June 2026, covering preparation, pretest, three instructional meetings, classroom observation, posttest, and data analysis. The intervention was implemented in three mathematics learning meetings, with observations conducted during each meeting.

Researcher and Teacher Roles

Research activities were coordinated and monitored by the researcher, while instruction was delivered by the respective Grade III classroom teachers. Class III A received CRT assisted by interactive media, whereas Class III B received conventional mathematics instruction. Pre-intervention coordination addressed the schedule, instructional procedures, media use, classroom management, and data collection. No separate formal teacher training was conducted before the intervention.

Research Permission and Ethical Consideration

Research implementation at SDN 2 Ngraho was supported by an official research permission letter from Universitas Persatuan Guru Republik Indonesia (UPGRIS). Administrative coordination with the principal and Grade III teachers was completed before data collection. Research procedures were explained to relevant school personnel, and student data were used solely for academic purposes without identifying individual students.

Intervention Implementation

Experimental Group

Mathematics instruction integrated Culturally Responsive Teaching (CRT) with interactive media. Division concepts were connected with familiar cultural contexts through dakon as a concrete resource for equal grouping. Contextual problems involving everyday situations and traditional food distribution helped students relate division to their experiences. An Interactive Flat Panel (IFP) provided visual materials, videos, digital questions, quizzes, and practice activities. Meeting 1, cultural contextualization and division using dakon; meeting 2: mathematical representation and contextual problem solving; meeting 3: interactive practice and application using IFP.

Control Group

Mathematics instruction in the control group addressed the same division content and learning objectives as the experimental group. Conventional mathematics instruction was maintained without the integrated CRT activities and interactive-media treatment used in the experimental group. Comparable mathematical content and learning objectives allowed the instructional approach to remain the principal difference between the two groups.

Implementation of CRT Principles
CRT implementation integrated cultural contextualization, dakon-based equal grouping, student interaction, and everyday problem solving. Interactive support through the IFP provided visual materials, digital questions, quizzes, and practice activities.

Data Collection Techniques and Research Instruments
Quantitative data were collected through classroom observation and mathematics achievement testing, with documentation used to support the research record. Learning activity and mathematics achievement served as the two dependent variables. The research instrument information is consistent with the documented method, which specifies an 18-item observation sheet for learning activity and a 20-item mathematics achievement test.

Learning Activity Instrument
Learning activity was measured using an 18-item structured observation sheet covering attention, discussion, listening, task completion, media use, problem solving, and emotional engagement. The maximum score was 72, with scores of 61–72 classified as very active, 46–60 as active, 31–45 as fairly active, and 18–30 as less active. Classroom observations were conducted by the researcher during the three instructional meetings using consistent indicators and scoring criteria.

Mathematics Achievement Instrument
Mathematics achievement was measured using a 20-item multiple-choice test with four options, comprising 10 items on division concepts and 10 items on problem-solving applications. The test was administered as both pretest and posttest.

Instrument Validity and Reliability
Content validity was assessed through expert judgment involving a Grade III teacher and the thesis supervisor. Item quality was further examined through point-biserial validity, difficulty, and discrimination analyses. Internal consistency was assessed using Cronbach's alpha, with $\alpha \geq .70$ as the minimum criterion. Items were revised or retained based on the instrument-quality results. Classroom observations were conducted by the researcher using the same 18-item observation sheet, four-point scale, and predetermined criteria across all three meetings.

Research Procedure
Research implementation proceeded from preparation to interpretation. Image 1 presents the complete research procedure, from instrument development and pretest administration to intervention, posttest, data analysis, and interpretation.

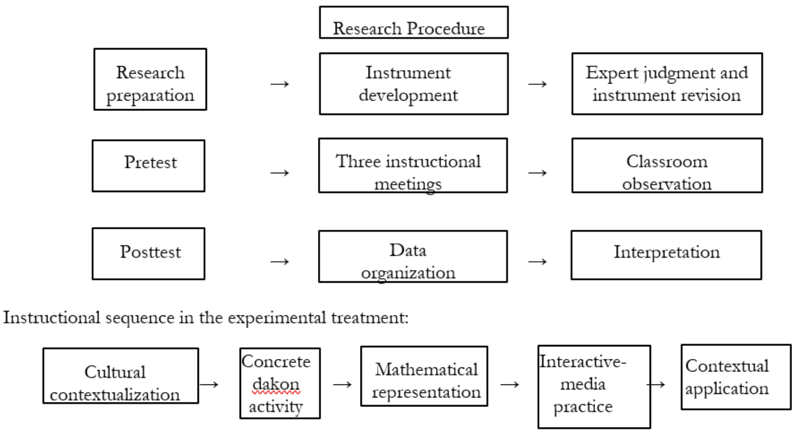

Image 1. Research Procedure

Image 1 presents the research procedure from preparation and instrument development through intervention, posttest, data analysis, and interpretation. The experimental treatment followed cultural contextualization, dakon activity, mathematical representation, interactive-media practice, and contextual application.

Data Analysis

Descriptive statistics were calculated for learning activity and mathematics achievement. Normality was assessed using the Shapiro–Wilk test, while variance homogeneity was examined using Levene's test ($p = 0.10$ for learning activity; $p = 0.48$ for mathematics achievement). Independent-samples t-tests examined group differences in learning activity, $t(26) = 5.92$, $p < .001$, and mathematics achievement, $t(26) = 3.85$, $p = .001$. MANOVA examined the simultaneous effect of CRT assisted by interactive media on both dependent variables. Pillai's Trace was used because the study involved two related outcomes. The covariance assumption was satisfied (Box's M = 3.05, $p = 0.42$). MANOVA indicated a significant multivariate effect, Pillai's Trace = 0.63, $F(2,25) = 21.75$, $p < .001$, partial $\eta^2 = 0.63$. Statistical analyses were conducted using SPSS with $\alpha = 0.05$.

Results and Discussion

Instrument Validity and Reliability

Instrument quality was assessed before hypothesis testing. The Mathematics Achievement Test and Learning Activity Observation Sheet demonstrated high internal consistency, with Cronbach's alpha coefficients of 0.94 and 0.95, respectively. Both coefficients exceeded the 0.70 criterion, indicating that the instruments provided consistent measurements for subsequent analysis.

Table 3. Reliability Statistics

Cronbach's Alpha	N of Items
0.94	20

Descriptive Statistics

Descriptive statistics were calculated to examine students' mathematics achievement before and after the intervention. The experimental and control groups showed comparable pretest means, while the experimental group obtained a higher posttest mean after the intervention. Table 4 presents the descriptive results. Measures of central tendency and score dispersion are presented in Table 4.

Table 4. Descriptive Statistics

Variable	Group	N	Mean	Std. Deviation	Minimum	Maximum
Pretest	Experimental	14	43.50	15.46	21	71
	Control	14	42.36	13.73	20	64
Posttest	Experimental	14	83.07	10.03	67	95
	Control	14	69.14	9.05	52	82

Table 5 shows increased mathematics achievement in both groups following the intervention. The experimental group improved from 43.50 at pretest to 83.07 at posttest, while the control group increased from 42.36 to 69.14. The experimental group therefore showed a greater mean improvement than the control group. Comparable pretest means also indicate similar initial mathematics achievement before the intervention.

Assumption Tests
Assumption testing preceded the inferential analysis to determine whether parametric statistical procedures were appropriate for the dataset. Because each class included fewer than 50 students, normality was assessed using the Shapiro–Wilk procedure. Results of the normality test are presented in Table 5.

Table 5 Tests of Normality

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	Eksperimen_SDN 2 Ngraho	.073	14	.200*	.972	14	.901
	2.00	.082	14	.200*	.974	14	.923
Postest	Eksperimen_SDN 2 Ngraho	0.15	14	0.20*	0.89	14	0.09
	2.00	0.09	14	0.20*	0.97	14	0.87

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Table 5 summarizes the Shapiro–Wilk normality test results. All significance values exceeded 0.05, indicating that the mathematics achievement data were normally distributed across the experimental and control groups. The normality assumption was therefore satisfied for subsequent parametric analyses.

Homogeneity of Variance
We evaluated equality of score variances across participating classes before inferential analysis using Levene's test. Statistical evidence supporting this assumption is summarised in Table 6.

Table 6. Levene's Test for Equality of Variances

		F	Sig.	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre Test	Equal Variances Assumed	0.17	0.67	1.14	5.52	-10.21	12.50
	Equal Variances Not Assumed			1.14	5.52	-10.22	12.51
Pos Test	Equal Variances Assumed	0.50	0.48	13.9	3.61	6.50	21.35
	Equal Variances Not Assumed			13.92	3.61	6.49	21.35

Table 7 shows that the significance values obtained from Levene's Test exceeded the 0.05 criterion for both the pretest and posttest. The results in Table 7 support equal score variances across the participating classes. Because variance homogeneity was confirmed, subsequent Independent Samples *t*-test analyses were interpreted using the Equal variances assumed procedure.

Equality of Covariance Matrices
We evaluated equality of covariance matrices before conducting the multivariate analysis to verify an additional assumption required for Multivariate Analysis of Variance (MANOVA). We assessed this using Box's M test, and present the results in Table 7.

Table 7. Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices[a]	
Box's M	3.05
F	.93
df1	3
df2	121680.000
Sig.	.424

Results of Box's M analysis are summarized in Table 8. A significance value above the established threshold indicates comparable covariance matrices across the participating classes. Fulfillment of this multivariate assumption supported the application of MANOVA to examine the simultaneous effects of Culturally Responsive Teaching assisted by interactive media on students' learning activity and mathematics achievement.

Effect of Culturally Responsive Teaching Assisted by Interactive Media on Learning Activity (H1)

Students' learning activity was compared across the participating classes using an independent-samples *t*-test. After confirming that the statistical assumptions were met, the analysis examined the effectiveness of Culturally Responsive Teaching assisted by interactive media. Table 8 summarises the corresponding results.

Table 8. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Activitys	Equal variances assumed	2.85	0.10	5.92	26	.000	24.64	4.16	16.08	33.19
	Equal variances not assumed			5.92	21.88	.000	24.64	4.16	16.01	33.27

Table 8 indicates a statistically significant difference in students' learning activity between the experimental and control groups. Students receiving Culturally Responsive Teaching assisted by interactive media demonstrated higher learning activity than those receiving conventional instruction, with a mean difference of 24.64 points. The finding supports H1 and indicates greater classroom participation among students in the experimental group.

Effect of Culturally Responsive Teaching Assisted by Interactive Media on Mathematics Achievement (H2)

Differences in mathematics achievement were evaluated using the Independent Samples *t*-test following confirmation that all prerequisite assumptions had been fulfilled. This analysis examined the effect of Culturally Responsive Teaching assisted by interactive media on the second research outcome. Table 9 summarises the statistical findings.

Table 9. Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Posttest	Equal variances assumed	0.50	0.48	3.85	26	.001	13.92	3.61	6.50	21.35
	Equal variances not assumed			3.85	25.73	.001	13.92	3.61	6.49	21.3

Table 9 shows a statistically significant difference in mathematics achievement between the experimental and control groups. Students receiving Culturally Responsive Teaching assisted by interactive media achieved higher posttest scores than those receiving conventional instruction, with a mean difference of 13.92 points, $t(26) = 3.85$, $p = .001$, 95% CI [6.50, 21.35]. The finding supports H2 and indicates greater mathematics achievement in the experimental group.

Improvement in Mathematics Achievement

We analysed normalised gain (N-gain) scores to compare the magnitude of learning improvement under each instructional approach. We used the independent-samples t-test for statistical comparisons, and Table 10 summarises the findings.

Table 10. Independent Samples Test for N-Gain Scores

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
N Gain	Equal variances assumed	23.19	.00	9.16	26	.00	0.25	0.02	0.19	0.30
	Equal variances not assumed			9.16	15.41	.00	0.2	0.02	0.19	0.31

Table 10 indicates a statistically significant difference in normalized gain scores between the experimental and control groups. Students receiving Culturally Responsive Teaching assisted by interactive media demonstrated greater normalized learning improvement than those receiving conventional instruction, with $t(26) = 9.16$, $p < .001$. The finding provides additional evidence of greater mathematics learning gains in the experimental group.

Effect Size

Effect size analysis was conducted to determine the practical significance of Culturally Responsive Teaching assisted by interactive media beyond statistical significance. Cohen's *d*, Hedges' correction, and Glass's delta were calculated to estimate the magnitude of the treatment effect. Table 11 presents the effect size estimates.

Table 11. Independent Samples Effect Sizes

	Point Estimate	95% Confidence Interval	
		Lower	Upper
Cohen's d	3.46	2.25	4.64
Hedges' correction	3.36	2.19	4.51
Glass's delta	8.37	5.10	11.62

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

The effect-size estimates indicate a substantial practical difference in normalized mathematics learning improvement between the two groups. The large Cohen's *d* and Hedges' correction values, together with the corresponding confidence intervals, show that the experimental group achieved markedly greater learning gains than the control group.

Simultaneous Effect of Culturally Responsive Teaching Assisted by Interactive Media on Learning Activity and Mathematics Achievement (H3)

Following the separate analyses of learning activity and mathematics achievement, multivariate analysis was conducted to determine whether both outcomes responded concurrently to the instructional intervention. Multivariate Analysis of Variance (MANOVA) was selected because the research examined two related dependent variables within a single analytical model. Statistical evidence from the multivariate analysis is summarized in Table 12.

Table 12. Multivariate Tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Intercept	Pillai's Trace	0.98	1172.64[b]	2.00	25.00	0.00	0.98	2345.29	1.00
	Wilks' Lambda	0.01	1172.64[b]	2.00	25.00	0.00	0.98	2345.29	1.00
	Hotelling's Trace	93.81	1172.64[b]	2.00	25.00	0.00	0.98	2345.29	1.00
	Roy's Largest Root	93.81	1172.64[b]	2.00	25.00	0.00	0.98	2345.29	1.00
Class	Pillai's Trace	0.63	21.75[b]	2.00	25.00	0.00	0.63	43.51	1.00
	Wilks' Lambda	0.36	21.75[b]	2.00	25.00	0.00	0.63	43.51	1.00
	Hotelling's Trace	1.74	21.75[b]	2.00	25.00	0.00	0.63	43.51	1.00
	Roy's Largest Root	1.74	21.75[b]	2.00	25.00	0.00	0.63	43.51	1.00

a. Design: Intercept + Class
b. Exact statistic
c. Computed using alpha = 0.05

Table 13 shows a significant multivariate effect of Culturally Responsive Teaching assisted by interactive media on learning activity and mathematics achievement, with Pillai's Trace = 0.63, $F(2,25) = 21.75$, $p < .001$, and partial $\eta^2 = 0.63$. The significant multivariate result indicates a combined difference in learning activity and mathematics achievement between the experimental and control groups. The partial η^2 value indicates a substantial multivariate effect, supporting H3.

Discussion

Higher learning activity in the experimental group suggests that CRT assisted by interactive media provided greater opportunities for participation through attention, discussion, questioning, problem solving, and task completion (Quane & Ní Ríordáin, 2025). Dakon provided a familiar concrete context for understanding division through equal grouping, while interactive media supported visual representation, digital questions, quizzes, and practice (Basuki et al., 2026). Cultural familiarity and interactive activities may therefore have encouraged students to participate more actively (Singh & Rajendran, 2024; Widana, 2022). However, because the intervention combined CRT, dakon, contextual problems, and interactive media, the findings reflect the integrated instructional approach rather than the independent effect of CRT alone (Dreher et al., 2024).

Higher mathematics achievement in the experimental group indicates that the intervention supported students' understanding and application of division. Dakon provided concrete experience with equal grouping before students moved to mathematical representation and contextual application, while interactive media offered additional visual and practice opportunities. Familiar situations involving equal distribution and traditional food also connected mathematical concepts with students' everyday experiences, helping bridge prior knowledge and formal mathematics. These findings extend previous research on culturally responsive mathematics by integrating cultural experience, concrete manipulation, and interactive digital support in a third-grade division context. Nevertheless, the results should be interpreted cautiously because the intervention involved only three instructional meetings in one school, and the combined use of CRT, dakon, contextual problems, and interactive media prevents the independent contribution of each component from being determined (Hay, 2024; Robson & LeVoguer, 2024; Rifayanti et al., 2024; Lehtinen et al., 2025).

Active participation provided opportunities to ask questions, explain strategies, receive feedback, practice procedures, and correct misconceptions, potentially supporting mathematical understanding. A significant MANOVA result indicates a combined effect on learning activity and mathematics achievement, while multivariate analysis provides a broader assessment of instructional effectiveness by examining classroom participation and mathematics achievement within one analytical framework. Similar educational implications have been reported by Aktaş et al. (2023); J. Li & Xue, 2023; Powell & R, 2023), who consistently concluded that technology-supported learning environments become more effective when they facilitate active engagement, contextual learning experiences, and meaningful interaction during mathematics instruction.

The principal contribution lies in integrating Culturally Responsive Teaching, culturally familiar concrete resources, interactive media, and two complementary learning outcomes within one elementary mathematics intervention. Unlike studies that commonly examine culturally responsive pedagogy, technology-supported learning, student engagement, or mathematics achievement separately, the present study evaluates learning activity and mathematics achievement simultaneously through MANOVA. Dakon functions as a cultural learning resource for representing equal grouping, helping students move from familiar experiences toward formal mathematical representations, while interactive media connects concrete experiences with visual and digital activities. Consequently, novelty lies in the integration of CRT and interactive media with a culturally familiar concrete resource and the simultaneous examination of behavioral and cognitive outcomes, particularly within an Indonesian primary mathematics context.

Integrating Culturally Responsive Teaching, culturally familiar concrete resources, interactive media, and two complementary learning outcomes represents the principal contribution of the study. Unlike studies that examine culturally responsive pedagogy, technology-supported learning, student engagement, or mathematics achievement separately, the present study evaluates learning activity and mathematics achievement simultaneously through MANOVA. Dakon functions as a cultural learning resource for representing equal grouping, helping students move from familiar experiences toward formal mathematical representations, while interactive media connects concrete experiences with visual and digital activities. Novelty lies in integrating CRT and interactive media with a culturally familiar concrete resource and examining behavioral and cognitive outcomes simultaneously in an Indonesian primary mathematics context.

Using 28 third-grade students from one school and only three instructional meetings limits generalizability and long-term interpretation. Structured observation by the researcher may also involve observer-related subjectivity despite predetermined indicators and scoring criteria. Because CRT, dakon, contextual problems, and interactive media were implemented as an integrated intervention, their individual contributions could not be isolated. Future research should involve larger samples across multiple schools, longer interventions, additional observers, and comparative or factorial designs to examine the distinct contributions of CRT, interactive media, and their combination to learning activity and mathematics achievement.

Conclusion

Integrating Culturally Responsive Teaching (CRT) with interactive media provides a practical instructional approach for improving elementary students' learning activity and mathematics achievement. Higher learning activity and mathematics achievement in the experimental group, together with the significant multivariate effect, indicate that the integrated approach can support both students' participation during learning and their mathematical performance. Simultaneous evaluation of behavioral and cognitive outcomes through MANOVA also provides a more comprehensive view of instructional effectiveness. For educational policy and teacher professional development, CRT-integrated mathematics instruction can be considered in teacher training and instructional planning to help teachers connect local cultural experiences with interactive learning activities.

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