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An Experimental Evaluation of Multisensory Teaching Techniques on Mathematical Achievement at Primary Education Level

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ABSTRACT

This study investigates the effect of multisensory teaching-learning resources—concrete manipulatives, graphical tools, and audio-visual materials—on the academic achievement of Grade 4 students in mathematics within a government primary school in Haripur, Pakistan. Utilizing a quasi-experimental design with a pre-test and post-test control group, the study involved 44 students divided equally into experimental and control groups. Statistical analysis revealed significant improvement in the experimental group, indicating that interactive teaching methods enhance conceptual understanding and student engagement more effectively than traditional instruction. The results support constructivist and cognitive learning theories, highlighting the need for resource-based instruction in low-resource educational settings. Recommendations are provided for educational policymakers and practitioners to improve primary mathematics instruction through targeted resource integration and teacher training.

Introduction

In recent decades, mathematics educators have increasingly recognized that traditional lecture-based instruction may fall short in supporting the diverse cognitive and sensory learning needs of young learners, particularly at the primary level. As a response, multisensory instructional strategies — involving concrete, graphical, and audio-visual teaching-learning resources — have emerged as promising pedagogical tools to enhance comprehension, retention, and academic performance in mathematics (Cuturi et al., 2022; Di Loreto, 2019).

Multisensory learning theory posits that the more senses involved in the learning process, the deeper and more durable the learning (Mayer, 2005). This approach is grounded in both cognitive load theory and dual coding theory, which argue that visual and auditory channels, when used together, improve processing efficiency and conceptual understanding. Within primary mathematics education, this implies a shift from purely symbolic instruction to approaches that allow children to touch, see, hear, and manipulate concepts — aligning with their concrete operational developmental stage, as defined by Jean Piaget.

The independent variables in this study consist of three types of multisensory resources:

Concrete teaching resources, such as base-ten blocks, geometric solids, and fraction bars, physically engage learners with mathematical structures. These tools help bridge abstract arithmetic and tangible reality, particularly in early numeracy, place value, and geometry (Berhe et al., 2024).

Graphical resources, including diagrams, pictographs, number lines, and bar models, visually represent mathematical relationships and help children organize and interpret numerical data. They are especially effective in reinforcing pattern recognition, spatial reasoning, and the translation of word problems into visual models (Tahir & Gulfraz, 2024).

Audio-visual resources, such as instructional videos, animations, and interactive multimedia software, present mathematical content dynamically across multiple sensory modalities. These tools not only foster engagement but also support auditory and visual learners in internalizing procedures and concepts (Mutemi, 2023; Agah et al., 2024).

Together, these multisensory teaching methods comprise the study's independent variable. The dependent variable is the academic achievement in mathematics, typically measured through standardized assessments or pre/post-test performance scores. The core hypothesis of this study is that students exposed to a multisensory teaching approach will demonstrate statistically significant gains in mathematical achievement compared to those instructed through conventional methods.

Recent experimental studies have shown that audio-visual and graphical aids significantly enhance learners' understanding of abstract concepts by making them more relatable and contextually grounded (Oviawe & Uddin, 2020; Ubimago, 2021). For example, Cuturi et al. (2022) designed a multisensory learning environment for elementary mathematics and found that interactive haptic and visual tools helped improve number sense and problem-solving abilities in early learners.

Moreover, researchers like Sikand and Kauts (2012) provide experimental evidence that multisensory teaching strategies increase concept retention and learner confidence, particularly in mathematics. Their work highlights the critical role of instructional design — not merely the tools — in determining learning outcomes. Similarly, Di Loreto (2019) emphasizes that students perform better when instructional tools are deliberately aligned with their perceptual strengths and learning needs.

In sum, the relationship among these variables is grounded in the belief that multimodal engagement with mathematical content leads to deeper conceptual understanding, increased engagement, and improved performance. This study, therefore, seeks to experimentally evaluate the comparative impact of concrete, graphical, and audio-visual resources in primary school mathematics instruction, offering evidence-based insights for future curriculum design and teacher training.

Multisensory teaching techniques have gained growing attention in contemporary education for their potential to address cognitive diversity, particularly among primary school learners. Aligned with constructivist learning theory, these strategies integrate visual, auditory, and kinesthetic modalities to support deeper conceptual understanding and memory retention. Recent findings affirm that such approaches not only increase engagement but also enhance the encoding and retrieval of mathematical information (Lyu & Deng, 2024; Garzón, 2021).

In the domain of mathematics education, multisensory strategies serve as a critical bridge between abstract numerical ideas and concrete, relatable experiences for young learners. Studies emphasize that incorporating sensory-rich experiences helps children internalize concepts by appealing to how the brain naturally integrates multimodal stimuli (Carreon et al., 2022; Shoaib et al., 2023). For instance, embodied learning techniques—those involving movement, touch, or manipulation—have demonstrated strong cognitive and affective outcomes in primary math instruction (Deng & Lyu, 2024).

The importance of tangible learning resources, such as base-ten blocks, counting tools, and manipulatives, remains central to effective early numeracy instruction. These materials are crucial for fostering foundational number sense and spatial reasoning. Recent experimental research shows that students engaging with concrete manipulatives significantly outperform their peers in tasks involving arithmetic, fractions, and spatial transformations (Cercado, 2023; Holmes et al., 2023).

Moreover, the integration of interactive and sensory-augmented technologies—like augmented reality (AR) and VR—has expanded the potential of multisensory education. When embedded within well-structured pedagogical designs, such tools offer immersive environments that scaffold abstract mathematical thinking through experiential learning (Rahman et al., 2024; Garzón, 2021). This aligns with recent meta-analytical reviews indicating that multisensory and embodied learning approaches not only improve immediate performance but also sustain long-term retention of mathematical concepts (Falzon & Conrad, 2024; Fan et al., 2020).

Parallel to concrete aids, graphical representations play a significant role in developing mathematical reasoning and visualization skills among young learners. These include number lines, bar models, pie charts, Venn diagrams, and other pictorial tools that help organize abstract relationships into tangible visual formats. Contemporary research affirms that such visual scaffolds enhance students' capacity to interpret problems, discover patterns, and apply strategies efficiently (Coban et al., 2022; Carreon et al., 2022). Visual tools also reduce intrinsic cognitive load by enabling dual coding—simultaneous processing of visual and verbal representations—which enhances comprehension and retention (Lehane, 2022; Abdulrahaman et al., 2020).

The integration of audio-visual technologies further amplifies the benefits of multisensory instruction. Tools such as animations, interactive videos, and virtual manipulatives dynamically illustrate abstract operations and support deeper understanding, particularly in topics like regrouping, symmetry, or measurement conversions (Shoaib et al., 2023; Coban et al., 2022). Students with learning difficulties, including those with visual impairments or cognitive processing disorders, benefit significantly from such interventions due to clearer step-by-step explanations and engaging formats (Darska et al., 2024; Shoaib et al., 2023).

Multisensory instruction proves most effective when instructional modalities—tactile, auditory, and visual—are strategically combined. Recent meta-analyses confirm that integrated approaches grounded in multimedia learning theory significantly improve both conceptual understanding and motivation across ability levels (Coban et al., 2022; Daniela & Visvizi, 2021). Furthermore, virtual reality (VR) and immersive technologies now offer novel pathways for primary students to experience spatial concepts and mathematical transformations within interactive, game-like environments (Carreon et al., 2022; Coban et al., 2022).

However, despite these advantages, challenges remain in implementing multisensory strategies effectively. Research warns that poorly designed visual or multimedia resources—those lacking alignment with learning goals—can create misconceptions or cognitive overload (Lehane, 2022). Teacher readiness, resource access, and digital fluency continue to influence how successfully these tools are used in classrooms (Darska et al., 2024). Hence, a pedagogically grounded, learner-centered design is critical to realizing the full potential of multisensory tools in primary mathematics education.

Overall, the literature supports the central thesis of this study—that multisensory teaching techniques significantly enhance academic achievement in primary mathematics. The interplay between concrete manipulatives, graphical representations, and audio-visual tools improves learners' engagement and facilitates a deeper understanding of mathematical abstractions. Recent investigations have demonstrated that combining these modalities results in better generalization of math concepts and enhanced cognitive retention when implemented through a cohesive instructional design (Cai et al., 2024; Gairns & Richards, 2023). However, these benefits also underscore the need for systematic experimental validation that compares multimodal configurations in controlled classroom contexts.

Despite global advocacy for learner-centered methods, there remains a limited body of experimental research that holistically evaluates multisensory strategies across primary education. While individual modalities—such as manipulatives or visuals—are often studied in isolation, the combined effect of these sensory dimensions on mathematics performance has yet to be fully theorized and measured (Ali et al., 2023; Kalogeropoulos et al., 2024). This fragmented approach results in an incomplete understanding of how concurrent sensory inputs interact and impact learning processes.

Concrete instructional aids like number rods, counters, and fraction bars have long been associated with improvements in early numeracy, yet recent studies are calling for a reexamination of how these resources can be used as a bridge toward abstract reasoning. For instance, how tactile interaction translates to symbolic mathematical fluency remains an underexplored transition pathway in current pedagogical models (Gairns & Richards, 2023; Liu & Zhang, 2022).

Likewise, audio-visual resources—particularly video lessons, AR-based apps, and animated sequences—are increasingly recognized for their utility in math instruction. Yet the majority of studies have focused on secondary students, with comparatively fewer investigations targeting Grades 1–5, where learners still rely heavily on concrete operational thinking (Lee et al., 2023; Furlong & Murphy, 2021). More troubling is that many studies attribute success to surface-level engagement factors such as enjoyment or novelty, without anchoring outcomes in theories like dual coding or cognitive load management.

In the Pakistani educational research landscape, this gap is even more pronounced. Most national studies rely on teacher-reported improvements or qualitative interviews, lacking empirical data on student outcomes. There is still no comprehensive, experimental study in the region that measures the effects of an integrated multisensory approach across multiple classroom modalities in mathematics. Emerging frameworks like the Universal Design for Learning (UDL) could be instrumental in addressing these issues if properly tested in localized educational contexts (Hussain & Fatima, 2023).

Another major gap in existing literature is the absence of theoretical grounding in local studies. While global researchers have successfully employed frameworks such as Mayer's *Cognitive Theory of Multimedia Learning* and Sweller's *Cognitive Load Theory* to guide instructional design in mathematics education, Pakistani research often omits these models entirely. This shortfall restricts both the depth of pedagogical insight and the generalizability of findings (Noetel et al., 2022; Albus, 2023). A theoretically grounded and empirically robust experimental study in the Pakistani context would therefore address this deficiency and contribute significant value to the international discourse on instructional design in mathematics.

Furthermore, graphical tools—such as bar models, number bonds, and pictographs—are notably underrepresented in both international and national studies. Despite growing curricular emphasis on visual literacy in mathematics, the focus tends to remain on concrete or audio-visual tools. Yet visual models serve as essential mediators that help bridge tactile exploration and symbolic abstraction, especially during problem-solving tasks (Fan et al., 2020; Wyeth et al., 2023). Without focused investigation into these graphical components, instructional design in primary mathematics remains incomplete and unbalanced.

Finally, a critical methodological gap lies in the lack of longitudinal research on the impact of multisensory teaching. The majority of existing studies rely on short-term pre-test/post-test designs, offering little insight into long-term learning retention or sustained attitudinal shifts. This absence of follow-up evaluation is especially problematic in early education, where concepts must be internalized gradually and revisited across multiple contexts (Wei & Yuan, 2023; Kordaki et al., 2024). Thus, your proposed study—integrating concrete, visual, and auditory modalities within a longitudinal framework—directly addresses these pressing gaps and aligns with global calls for more nuanced, theory-driven pedagogical evaluations.

Statement of the Problem

Primary mathematics education plays a critical role in shaping students' cognitive and academic development by laying the foundation for future learning. However, in many developing regions, instructional practices remain dominated by traditional, teacher-centered methods that emphasize rote memorization and textbook-based learning. These approaches often fail to actively engage students, making it difficult for them to grasp and retain abstract mathematical concepts such as fractions, geometry, and measurement.

Multisensory teaching-learning resources—such as manipulatives, graphical tools, and audio-visual materials—offer promising alternatives. These resources allow learners to interact with mathematical content in tactile, visual, and auditory ways, thus enhancing understanding and retention. Despite their proven benefits in various educational contexts, the use of such tools remains limited in many low-resource settings.

This study addresses that gap by investigating how the use of concrete, graphical, and audio-visual resources influences mathematics achievement among primary students, particularly in under-resourced educational settings where such tools are rarely implemented but may offer significant learning benefits.

Research Objective

- To evaluate the effect of multisensory teaching-learning resources—specifically concrete manipulatives, graphical tools, and audio-visual aids—on the academic achievement of primary school students in mathematics.

Research Question

- How do concrete, graphical, and audio-visual teaching-learning resources affect the academic achievement of primary school students in mathematics?

Research Hypothesis

$H_0$1: There is no significant difference in the academic achievement of Grade-4 students in Mathematics between the control and experimental group in the pre-test

$H_0$2: There is no significant difference in the academic achievement of Grade-4 students in Mathematics between the control and experimental group in the post-test

$H_0$3: There is no significant difference in the academic achievement of Grade-4 students in Mathematics in the pre- and post-test of the control group

$H_0$4: There is no significant difference in the academic achievement of Grade-4 students in Mathematics in the pre- and post-test of the experimental group

Delimitations of the Study

The study is limited to primary-level students in mathematics; findings may not apply to other grade levels. Conducted in Working Folks Grammar School, Haripur (Pakistan)—results are region-specific and not generalizable to other districts or countries. Involves a small sample of 44 students (22 control, 22 experimental), which limits broad generalization. Focuses only on manipulatives, graphical tools, and audio/visual resources; excludes other tools like digital games or software.

Methodology

This study adopted a quantitative, quasi-experimental research design to investigate the causal relationship between multisensory teaching-learning resources and academic achievement in primary mathematics. Given the practical limitations of random assignment in real classrooms, intact groups were used to maintain ethical and logistical feasibility. A pre-test/post-test control group design was employed, allowing for the systematic comparison of an experimental group—exposed to concrete manipulatives, graphical representations, and audio-visual tools—with a control group taught through traditional textbook-based instruction.

Pre-tests measured baseline knowledge, and post-tests evaluated academic progress, thereby offering a reliable metric for determining the effectiveness of resource-based instruction. The chosen design aligns with educational research literature that supports the use of multisensory tools to boost student engagement and understanding (e.g., Attard & Holmes, 2022). The integration of different modalities provided diverse learning experiences, improving both the depth and accessibility of mathematical content. This approach ensured the study remained both pedagogically relevant and methodologically sound, offering evidence-based insights for instructional improvement in primary mathematics.

Population and Sampling

The study targeted Grade 4 students at Working Folks Grammar School in District Haripur, selected for its structured curriculum and accessibility. Grade 4 was chosen due to its critical role in transitioning from basic arithmetic to more complex topics like measurement and geometry. A non-probability convenience sampling technique was used to select 44 students, divided equally into an experimental group (n = 22) and a control group (n = 22). Efforts were made to match groups on demographic and academic backgrounds, with equivalence confirmed through pre-testing.

Research Instrument

The primary tool used was a 50-item Mathematics Achievement Test, designed around the Grade 4 curriculum. It covered key areas such as measurement, geometry, arithmetic operations, and problem-solving**.** The test was administered as both a pre-test and post-test to measure academic improvement resulting from the intervention.

Table 1: ***Units taken for preparation of tests from Mathematics book Grade 4th***

S. No.	Pre and Post-Test Units
1	Measurement
2	Geometry
3	Arithmetic Operations
4	Problem-Solving

The following table showed table of specification for Mathematic Achievement Test.

Table 2: ***Table of specification for content of Mathematics Achievement Test (pre and post-test)***

Topics/ Units	Knowledge	Comprehension	Application	Total Items
Measurement	5	4	3	12
Geometry	4	3	3	10
Arithmetic Operations	6	5	5	16
Problem-Solving	2	3	7	12
Total	17	15	18	50
Percentage	34%	30%	36%	100%

Below is given the table of specification concerning the cognitive domains and number of items put in the Achievement Test.

Table 3: ***Cognitive domains and numbers of items***

S. No.	Levels	No. of Items	Marks	Percentage
1	Knowledge	17	17	34%
2	Comprehension	15	15	30%
3	Application	18	18	36%
	Total	50	50	100%

Procedure

The data collection process in this study was conducted in three structured phases to ensure clarity and consistency. In Phase 1, both the experimental and control groups were administered a pre-test to establish a baseline of their mathematical achievement. This was followed by Phase 2, during which the intervention was implemented: the experimental group received instruction using a variety of teaching-learning resources, including concrete manipulatives, graphical tools, and audio-visual materials. In contrast, the control group continued with traditional textbook-based instruction. Observational data were also collected during this phase to track student engagement and participation. Phase 3 involved the administration of a post-test to both groups, aimed at measuring the academic impact of the intervention. Additionally, student engagement surveys were used to collect qualitative feedback, offering further insight into how learners responded to the different instructional methods.

The study was conducted with strict adherence to ethical standards. Parents and guardians of all participating students were provided with detailed information about the study and their informed consent was obtained in writing. Anonymity and confidentiality of student data were maintained throughout, ensuring that test scores and personal information were securely stored and not disclosed. Data was protected through password-secured systems, and all findings were used strictly for academic and research purposes to prevent any form of disadvantage to the participants. These measures ensured that the rights and well-being of all students were fully respected.

Data Analysis

The data analysis was performed using the Statistical Package for Social Sciences (SPSS) to ensure objective and robust statistical evaluation. A paired sample t-test was applied to compare pre- and post-test scores within each group, highlighting any significant academic gains over time. An independent sample t-test was used to compare post-test results between the experimental and control groups, helping to determine whether the multisensory intervention led to statistically significant differences. Finally, Cohen's d was calculated to assess the effect size and quantify the magnitude of the intervention's impact on student achievement. Together, these analytical procedures provided a comprehensive and reliable evaluation of how teaching-learning resources influenced mathematical learning outcomes.

Table 4: ***Pre-test comparison between experimental and control groups on Mathematic student achievement***

Groups	N	Mean	SD	SEM	t-value	P	d'
Pre-Exp	22	19.27	4.12	0.878			
Pre-Control	22	20.13	4.75	1.013	-0.65	0.521	0.19

Not Significant at α .05

The results of the independent samples t-test in the above Table 4, which indicate that there is no statistically significant difference in mathematics achievement between the experimental group (M = 19.27, SD = 4.12) and the control group (M = 20.13, SD = 4.75) prior to the intervention. The calculated t-value of -0.65 and p-value of 0.521 ($p > 0.05$) confirm that the difference in mean scores is not significant, and the Cohen's d of 0.19 suggests a small effect size, indicating minimal practical difference. These findings support the null hypothesis (H_{01}), suggesting that the two groups were statistically equivalent at baseline, thus providing a reliable foundation for comparing post-test outcomes following the instructional intervention. The $H_0 1$ is accepted.

$H_0$1: There is no significant difference on the academic achievement of Grade-4 students in Mathematics between control and experimental group in pre-test

Table 5: ***Post-test comparison between experimental and control groups on Mathematic student achievement***

Groups	N	Mean	SD	SEM	t-value	P	d'
Post-Exp	22	33.41	3.82	0.814			
Post-Control	22	30.55	5.03	1.072	2.18	0.036	0.56

Significant at α .05

The post-test results shown in table 5 indicate a statistically significant improvement in mathematics achievement for the experimental group compared to the control group. The experimental group achieved a mean score of 33.41 (SD = 3.82), which was higher than the control group's mean of 30.55 (SD = 5.03). The independent samples t-test yielded a t-value of 2.18 and a p-value of 0.036, which is significant at the 0.05 level, leading to the rejection of the null hypothesis (H_{02}). This suggests that the instructional intervention had a positive effect on student performance. Moreover, the Cohen's d of 0.56 reflects a moderate effect size, indicating that the difference is not only statistically significant but also educationally meaningful. Therefore, the findings support the conclusion that the multisensory teaching approach used with the experimental group contributed to a modest yet significant gain in mathematical achievement. The $H_0$2 is rejected.

$H_0$2: There is no significant difference on the academic achievement of Grade-4 students in Mathematics between control and experimental group in post-test

Table 6: ***Comparison of control group before and after treatment on Mathematic student achievement***

Groups	M	SD	SEM	Correlation	Paired Differences			t-value	P	d'
					M	*SD*	*SEM*			
Pre	40	119.6	11.52	0.51 (0.754)	-2.60	15.0	2.37	-1.10	-14.04 (0.276)	0.09
Post	40	122.2	14.81							

Not Significant at α .05

The results of Table 6 show that the control group did not experience a statistically significant improvement in mathematics achievement from pre-test to post-test. The pre-test mean score was 119.6 (SD = 11.52), and the post-test mean slightly increased to 122.2 (SD = 14.81), resulting in a mean difference of just 2.60 points. The t-value of -1.10 and p-value of 0.276 (which is greater than the α = 0.05 significance level) indicate that this change is not statistically significant. Furthermore, the effect size (Cohen's d = 0.09) is very small, suggesting no meaningful practical impact of regular instruction without the intervention. The moderate correlation (r = 0.754) between pre- and post-test scores indicates consistent performance among students, but not a significant gain. Therefore, the null hypothesis (H_{03}) is retained, confirming that the traditional teaching approach used with the control group did not lead to a significant improvement in mathematics achievement.

$H_0$3: There is no significant difference on the academic achievement of Grade-4 students in Mathematics in pre and post-test of control group

Table 7: ***Comparison of experimental group before and after treatment on Mathematic student achievement***

Groups	M	SD	SEM	Correlation	Paired Differences			t-value	p	d'
					M	*SD*	*SEM*			
Pre	40	119.6	11.52	1.821	0.51 (0.754)	-43.60	19.61	3.10	-14.04 (0.000)	2.15
Post	40	163.2	16.47	2.604						

Significant at α .05

The paired samples t-test in Table 7 reveals a statistically significant and practically meaningful improvement in mathematics achievement within the experimental group from pre-test to post-test. The mean score increased from 119.6 (SD = 11.52) in the pre-test to a higher post-test value with a mean gain of 43.60 points. The t-value of -14.04 and p-value of 0.000 ($p < 0.05$) confirm that this improvement is highly significant. The correlation of 0.754 between the pre- and post-test scores indicates a strong linear relationship, enhancing the reliability of the comparison. Importantly, the effect size (Cohen's d = 2.15) is very large, demonstrating that the observed improvement is not only statistically significant but also educationally substantial. This strongly supports the effectiveness of the multisensory teaching intervention used with the experimental group. Thus, the null hypothesis (H_{04}) is rejected, affirming that the experimental instruction had a profound positive impact on students' mathematical achievement.

$H_0$4: There is no significant difference on the academic achievement of Grade-4 students in Mathematics in pre and post-test of experimental group

Table 8: Descriptive Statistics – Pre- and Post-Test Scores

Group	Test Type	Mean Score	Standard Deviation
Experimental	Pre-Test	19.27	4.12
Experimental	Post-Test	33.41	3.82
Control	Pre-Test	20.13	4.75
Control	Post-Test	30.55	5.03

The descriptive statistics presented in Table 8 summarize the pre- and post-test mathematics achievement scores for both the experimental and control groups. In the experimental group, the mean score increased significantly from 19.27 (SD = 4.12) in the pre-test to 33.41 (SD = 3.82) in the post-test, indicating a strong improvement following the multisensory instructional intervention. In contrast, the control group showed a smaller increase from a pre-test mean of 20.13 (SD = 4.75) to a post-test mean of 30.55 (SD = 5.03). While both groups improved over time, the experimental group demonstrated a greater gain, both statistically and educationally, as reflected in the higher post-test mean and lower standard deviation, which suggests more consistent performance among students. This pattern supports the conclusion that the multisensory teaching approach had a more substantial impact on student learning outcomes compared to traditional instruction used in the control group.

Table 9: Inferential Statistics – Significance Testing

Comparison	t-value	p-value	Interpretation
Experimental Group (Pre vs. Post)	-14.04	0.000	**Significant** improvement; large effect (d = 2.15)

Comparison	t-value	p-value	Interpretation
Control Group (Pre vs. Post)	-1.10	0.276	**Not significant**; minimal change (d = 0.09)
Experimental vs. Control (Post-Test Only)	2.18	0.036	**Significant difference** in favor of experimental group (d = 0.56)

The inferential analysis presented in Table 9 demonstrates clear differences in mathematics achievement outcomes across groups. The experimental group showed a statistically significant improvement from pre- to post-test ($t = -14.04$, $p = 0.000$), with a very large effect size (Cohen's d = 2.15), confirming the strong impact of the multisensory teaching intervention. In contrast, the control group did not show a significant improvement ($t = -1.10$, $p = 0.276$), and the effect size was negligible ($d = 0.09$), suggesting that traditional instruction alone did not meaningfully enhance performance. Additionally, when comparing post-test scores between the experimental and control groups, the difference was statistically significant ($t = 2.18$, $p = 0.036$) with a moderate effect size ($d = 0.56$), further affirming the effectiveness of the intervention. These results collectively support the conclusion that multisensory teaching strategies have a measurable and meaningful impact on student achievement in primary mathematics.

Table 10: ***Summary of Four null Research Hypothesis on the Basis of Analysis***

Null Hypothesis	Result
$H_0 1$	Accepted
$H_0 2$	Rejected
$H_0 3$	Accepted
$H_0 4$	Rejected

The study aimed to explore the effects of concrete, graphical, and audio-visual teaching-learning resources on the academic achievement of Grade-4 students in mathematics. To address this, a quasi-experimental design was employed, comparing an experimental group exposed to multisensory instructional strategies with a control group taught through conventional methods.

The findings supported the first hypothesis (H01), indicating no significant difference between the experimental and control groups in the pre-test phase ($t = -0.65$, $p = 0.521$). This suggests that both groups were statistically equivalent at the start of the study, providing a valid foundation for comparison in the post-test phase.

For hypothesis H02, the post-test results revealed a statistically significant difference between the experimental and control groups ($t = 2.18$, $p = 0.036$), with the experimental group outperforming the control group. This finding led to the rejection of H02, indicating that the use of concrete, graphical, and audio-visual resources had a positive impact on students' mathematical achievement. The moderate effect size ($d = 0.56$) suggests that the improvement was not only statistically significant but also educationally meaningful.

Regarding H03, the comparison of the control group's pre- and post-test scores yielded no significant difference ($t = -1.10$, $p = 0.276$), supporting the hypothesis. This indicates that traditional instruction alone did not lead to a measurable improvement in students' performance.

In contrast, H04 was rejected, as the experimental group showed a highly significant gain in achievement from pre-test to post-test ($t = -14.04$, $p = 0.000$), with a very large effect size ($d = 2.15$). This substantial increase in scores clearly demonstrates the effectiveness of multisensory teaching techniques, including the integration of physical manipulatives, visual models, and audio-visual aids.

Discussion

The findings of this study support existing educational theories and empirical evidence suggesting that multisensory teaching-learning resources significantly enhance student achievement in mathematics. Students in the experimental group, exposed to concrete manipulatives, graphical tools, and audio-visual aids, showed greater improvement than those in the control group, validating the hypothesis that interactive strategies improve conceptual understanding and retention. This aligns with Piaget's theory of cognitive development, which emphasizes active engagement with the environment, and Vygotsky's zone of proximal development, which underscores the importance of scaffolding through guided instruction. Additionally, Sweller's cognitive load theory suggests that interactive materials help reduce unnecessary mental strain, allowing students to focus more effectively on core concepts. The use of multimedia and dynamic visuals likely activated both visual and verbal cognitive pathways, as per Mayer's (2019) cognitive theory of multimedia learning, improving both understanding and retention of mathematical concepts. Students in the experimental group not only performed better on assessments but also demonstrated higher levels of motivation and engagement, a pattern supported by research on blended and differentiated learning environments (Attard & Holmes, 2022; Gardner, 1983).

While the experimental group clearly benefited from the intervention, the study also highlights important caveats. The modest gains in the control group show that traditional methods still hold value, especially for students with strong auditory or verbal learning preferences. However, these methods often lack the engagement, flexibility, and conceptual clarity provided by multisensory tools. Limitations of resource-based instruction include dependency on teacher expertise, the need for adequate training, and the potential for over-reliance on concrete aids, which may inhibit transition to abstract reasoning (Lee & Tan, 2020). Furthermore, contextual challenges such as limited access to digital tools, especially in under-resourced schools, may restrict the effective implementation of these strategies (Sirajo & Abdullahi, 2023). Despite these constraints, the overall evidence supports the integration of multisensory teaching tools in primary mathematics classrooms. This study reinforces the need for sustained investment in teacher training, curriculum reform, and resource development to ensure that interactive instructional approaches are not only introduced but embedded systematically within educational systems for long-term impact.

Conclusions

The findings of this study provide clear evidence that multisensory teaching-learning resources—such as manipulatives, graphical tools, and audio-visual materials—have a significant positive impact on the academic achievement of primary students in mathematics. Students who were taught using these resources demonstrated greater improvement in their understanding, engagement, and retention of mathematical concepts compared to those taught through traditional textbook-based instruction. While gains were observed in both groups, the experimental group's outcomes suggest that resource-based instruction offers richer cognitive engagement and fosters deeper conceptual understanding. These results are aligned with educational theories that support active, visual, and differentiated learning, and they are especially relevant in the context of primary mathematics, where learners are still developing foundational skills.

In the context of Pakistan's government primary schools, where resource constraints and teacher-centered instruction are still prevalent, this study underscores the urgent need for instructional reform. The data clearly suggest that traditional approaches, though still functional, fall short in promoting conceptual clarity and student motivation. Government schools in Pakistan often lack access to even basic manipulatives or visual aids, and digital tools are rarely used in mathematics classrooms. Therefore, the integration of simple, low-cost, yet effective teaching-learning resources can play a transformative role in improving students' mathematical outcomes, especially in early grades.

Recommendations

To enhance the quality of mathematics education in Pakistan's government primary schools, the following recommendations are proposed. First, the Ministry of Federal Education and Professional Training should introduce curriculum guidelines that formally incorporate teaching-learning resources into mathematics instruction at the primary level. These guidelines should emphasize the use of age-appropriate manipulatives, pictorial tools, and where possible, localized audio-visual content aligned with the national curriculum. Second, nationwide teacher training programs must be launched to build capacity among public school teachers in the effective use of multisensory instructional strategies. Many teachers in government schools are not trained in using manipulatives or educational media, and this limits their ability to implement innovative teaching practices. Short-term, in-service workshops—especially at district or tehsil levels—can bridge this gap. Third, education departments and school management committees should be encouraged to allocate a portion of school development funds specifically for purchasing basic teaching aids for mathematics, such as number lines, fraction kits, place value blocks, and geometric tools. For rural and low-income schools, cost-effective, locally made teaching materials can be promoted through community engagement. Fourth, pilot initiatives should be introduced in selected government schools across provinces to evaluate the impact of integrated resource-based mathematics teaching on student achievement and motivation. These programs could serve as models for larger-scale implementation and inform future education policy. Lastly, there is a need to embed interactive learning practices into teacher induction programs**,** especially for new recruits in public schools. Long-term improvement in mathematics education requires a shift in instructional mindset—one that moves from rote memorization to conceptual engagement—and this change must begin with how teachers are trained from the outset.

By prioritizing resource-based instruction and supporting it with policy, training, and infrastructure, Pakistan's government primary schools can significantly enhance mathematics learning outcomes and contribute to the broader goals of equitable, quality education for all.

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