



Research Article

Improving Early Numeracy Skills Through Manipulative-Based Instruction: Evidence from Grade 1 Learners in Philippine Public Schools

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Abstract. Early numeracy skills form the foundation for later mathematical achievement, yet Filipino learners continue to demonstrate persistent gaps in foundational mathematics competencies. This quasi-experimental study examined the effectiveness of manipulative-based instruction in improving the early numeracy skills of Grade 1 learners in public elementary schools. A total of 360 Grade 1 learners from twelve public elementary schools in the Bauang North District, La Union, Philippines, participated in the study: 180 in the experimental group received six weeks of manipulative-based mathematics instruction, while 180 in the control group continued with conventional instruction. A researcher-developed 40-item Early Numeracy Skills Test aligned with the Department of Education's Most Essential Learning Competencies was administered as a pretest and posttest. Statistical analyses revealed that while both groups showed significant improvements, the experimental group demonstrated substantially greater gains ($t(179) = 20.15, p < .001$, Cohen's $d = 1.50$) compared to the control group ($t(179) = 4.23, p < .001$, Cohen's $d = 0.38$). Posttest comparisons confirmed a significant difference between groups ($t(358) = 14.21, p < .001$, Cohen's $d = 1.50$), with 75.55% of the experimental group achieving scores in the High or Very High proficiency range compared to only 29.44% of the control group. These findings provide robust evidence that manipulative-based instruction significantly enhances early numeracy development. The study contributes to the limited empirical research on concrete instructional approaches in Philippine early mathematics education and supports the integration of manipulative-based strategies as core pedagogical approaches in early grade mathematics instruction within Philippine public schools.

Keywords: Early numeracy; Grade 1 mathematics; Manipulative-based instruction; Philippine basic education; Quasi-experimental design.

Early numeracy forms the foundation upon which later mathematical learning is built. Long before learners encounter formal computation, they begin developing an understanding of numbers, quantities, patterns, and relationships that enables them to reason mathematically and solve everyday problems. These foundational competencies acquired in the early grades shape not only future achievement in mathematics but also learners' confidence in engaging with increasingly complex mathematical concepts (Chang, 2023). When these skills remain underdeveloped during the first years of schooling, subsequent learning becomes considerably more difficult, often resulting in persistent gaps that extend beyond the primary grades.

The challenge of developing early numeracy is a global concern. Across many countries, many children complete the primary grades without acquiring even the most basic mathematical competencies. For instance, the 2023



UNESCO Global Education Monitoring Report estimated that nearly two-thirds of learners worldwide do not reach minimum proficiency in mathematics by the end of primary school, with children in low- and middle-income countries bearing the greatest disadvantages (UNESCO, 2023). Evidence from large-scale international assessments further suggests that early weaknesses in number sense and mathematical reasoning seldom resolve on their own. Rather, they tend to accumulate over time, making more advanced mathematical concepts increasingly difficult to grasp (OECD, 2023). This means that strengthening numeracy at the start of children's schooling is not merely about improving test scores, but about giving learners the cognitive tools they need to participate more confidently in later learning.

The continuing concern over numeracy achievement is also evident in Philippine basic education. In the 2022 Programme for International Student Assessment (PISA), Filipino learners obtained a mean score of 355 in mathematics, substantially below the OECD average of 472, with a large proportion failing to attain the minimum level of mathematical proficiency expected for their age (OECD, 2023). Likewise, the 2019 Trends in International Mathematics and Science Study (TIMSS) found that Filipino Grade 4 learners ranked among the lowest-performing participants in mathematics, showing considerable difficulty with fundamental numerical concepts and problem solving (Mullis et al., 2020).

In the classroom, these outcomes are often linked to instructional practices that emphasize procedural fluency over conceptual understanding. Mathematics lessons in the early grades commonly rely on teacher demonstrations, repetitive drills, and workbook exercises that encourage learners to memorize procedures without fully grasping the numerical relationships underlying them (Oluwafemi et al., 2024). While these approaches may promote computational accuracy, they often offer limited opportunities for learners to explore mathematical ideas, test their reasoning, and construct meaning through active engagement. Consequently, mathematics may be experienced as a set of rules to follow rather than a system of concepts to understand and apply.

Contemporary perspectives in mathematics education argue that young children learn numerical concepts most effectively when abstract ideas are anchored in concrete experiences. Manipulatives such as counters, blocks, number rods, and other tangible materials allow learners to represent quantities, compare relationships, and visualize mathematical operations that might otherwise remain abstract (Bungao-Abarquez, 2020). Grounded in constructivist views of learning, manipulative-based instruction encourages learners to actively build mathematical understanding through exploration, interaction, and reflection. Studies have likewise shown that carefully integrated manipulatives support conceptual understanding, strengthen number sense, and increase learners' engagement during mathematics instruction (Angco & Angco, 2024). The CRA progression extends this view by proposing that conceptual understanding develops best when instruction moves deliberately from concrete experiences with physical objects to representational stages involving pictures and diagrams, and finally to abstract symbolic reasoning (Prosser & Bismarck, 2023). Cognitive load theory complements both perspectives by explaining why this progression matters: young learners have limited working memory, and abstract symbols introduced prematurely can overwhelm their cognitive resources, whereas concrete materials make mathematical relationships visible and reduce extraneous load (Gnawali, 2025). Together, these theories predict that instruction which begins with tangible materials and gradually bridges to symbolic understanding should produce stronger and more durable numeracy learning than instruction that begins and remains at the abstract level. This prediction directly motivates the manipulative-based intervention evaluated in the present study.

International evidence on this question has grown considerably, although it remains uneven. A scoping review by Byrne et al. (2023) synthesized a wide range of educational interventions involving physical manipulatives and concluded that such materials can improve learning outcomes, but also noted that effects vary substantially depending on how manipulatives are integrated into instruction and whether teachers are adequately prepared to use them purposefully. Muhammad et al. (2023) found significant performance gains among primary school pupils exposed to manipulatives in mathematics, while Sikhwari and Feza (2024) reported that manipulatives effectively mediated mathematics development for foundation-phase learners. Hurst and Linsell (2020), however, cautioned that manipulatives do not automatically produce understanding; their effectiveness depends on how well learners are supported in connecting concrete representations to mathematical ideas.

In the Philippine context, empirical studies examining manipulative-based instruction in authentic classroom

settings remain comparatively limited. Bungao-Abarquez (2020) documented the use of manipulatives in elementary mathematics but focused largely on teacher practices and perceptions rather than on learner achievement outcomes. Angco and Angco (2024) conducted a meta-synthesis of effective practices involving manipulatives but drew predominantly on international studies, underscoring the scarcity of rigorous Philippine-based experimental evidence. More broadly, Philippine research on early numeracy has tended to emphasize descriptive profiles of learner performance or the development of assessment tools, with comparatively few studies testing specific instructional interventions under regular classroom conditions. This means that while the potential of manipulatives is widely acknowledged, Philippine evidence remains limited on measurable gains in foundational numeracy from manipulative-based instruction, particularly among Grade 1 learners. Previous studies have thus not systematically addressed whether manipulative-based instruction, implemented within the constraints and realities of Philippine public elementary classrooms, produces significantly greater numeracy gains than conventional instruction, nor have they examined its effects across the broad range of early numeracy competencies expected of Grade 1 learners.

Despite the growing body of evidence supporting the use of manipulatives, much of the literature has focused on specific mathematical domains or has been conducted in contexts that differ considerably from Philippine public elementary schools. Moreover, previous studies have often examined isolated mathematical skills or older learners, leaving relatively limited classroom-based evidence on the effectiveness of manipulative-based instruction in strengthening the broad early numeracy competencies expected of Grade 1 learners. Given that Grade 1 marks the transition from informal numerical experiences to formal mathematics instruction, understanding how concrete instructional approaches influence numeracy development at this stage remains an important area of inquiry.

Within the Philippine context, empirical studies examining manipulative-based instruction in authentic classroom settings remain comparatively limited. While educational policies encourage learner-centered and activity-based instruction, evidence is still needed to show how these approaches translate into measurable improvements in foundational numeracy. Addressing this gap is particularly important in the early grades, where timely instructional interventions can prevent learning difficulties from becoming entrenched and can establish stronger foundations for future mathematical learning.

This study therefore examined the effectiveness of manipulative-based instruction in improving the early numeracy skills of Grade 1 learners in public elementary schools. By investigating the approach within an actual classroom context, the study generated empirical evidence on an instructional strategy that bridges concrete experiences with abstract mathematical thinking. The findings contribute to ongoing efforts to strengthen foundational mathematics education by providing insights into a learner-centered approach that supports conceptual understanding, meaningful engagement, and the development of essential numeracy skills.

Methodology

Research Design

This study employed a quasi-experimental pretest-posttest control group design. According to Miller et al. (2020), a quasi-experimental design allows researchers to evaluate the effects of an intervention using existing groups rather than randomly assigning participants, making it well suited to educational settings where intact classes are maintained. This design was adopted to determine whether manipulative-based instruction produces significant improvements in the early numeracy skills of Grade 1 learners compared with conventional mathematics instruction.

A quasi-experimental rather than a true experimental design was used because the study was conducted in naturally occurring classroom settings, where random assignment of learners was neither practical nor permissible. Existing Grade 1 classes from the participating schools served as the units of implementation. The experimental group (EG) received instruction through manipulative-based learning activities, while the control group (CG) continued with the conventional mathematics instruction regularly implemented in the classroom. This arrangement allowed the intervention to be examined under authentic teaching and learning conditions while minimizing disruption to normal school operations.

The pretest-posttest component enabled the researcher to assess changes in learners' numeracy skills before and

after the intervention. Pretest scores established the initial level of numeracy competence of both groups, while posttest scores measured learning gains following the instructional period. Comparing scores within each group and between groups strengthened the evaluation of the intervention's effectiveness and helped reduce potential threats to internal validity, such as maturation and testing effects, in accordance with established quasi-experimental procedures (Mustainah et al., 2023).

Participants and Sampling Technique

The participants were Grade 1 learners enrolled during the 2025–2026 school year in twelve public elementary schools in the Bauang North District. The study used purposive sampling because it required schools with Grade 1 classes that could accommodate the intervention under regular classroom conditions. As Khan (2020) noted, purposive sampling involves selecting participants based on characteristics that are directly relevant to the objectives of the investigation. In this study, the participating schools were organized into two groups to permit comparison between instructional approaches. Six schools formed the experimental group, where manipulative-based instruction was implemented: Acao, Baccuit, Ballay, Baratao, Bauang North Central, and Bawanta Elementary Schools. The remaining six schools served as the control group, where Grade 1 learners continued with the mathematics instruction ordinarily practiced in their classrooms: Bigbiga, Paringao, Pugo, San Agustin, Quinavite, and Eulogio Clarence M. De Guzman Jr. Elementary Schools.

Because random assignment of schools was not feasible, the two groups were formed through purposive matching based on key school characteristics to strengthen their comparability. The twelve participating schools were first profiled according to (a) school size and Grade 1 enrollment, (b) average class size, (c) availability of mathematics learning resources, (d) learners' prior numeracy performance based on school records, and (e) the socioeconomic profile of the surrounding community as reflected in the schools' reported learner backgrounds. Schools with comparable profiles were then paired, and one school from each pair was assigned to the experimental group while the other was assigned to the control group. All assignments were finalized in consultation with school heads and district supervisors to ensure that the arrangement was administratively feasible and consistent with existing school policies. This matching procedure was intended to reduce, though not eliminate, pre-existing differences between the groups. However, school-level factors such as teacher effectiveness, available resources, and socioeconomic conditions may still have influenced the results, and this limitation is discussed further in the study's concluding section.

Each participating school contributed an intact Grade 1 class of approximately thirty learners. Advisers identified the classes based on classroom assessments and professional observations indicating that the learners would benefit from additional support in early numeracy. For this study, learners in need of intervention were those who performed below expectations in foundational mathematical competencies, including number recognition, counting, number sense, basic operations, and simple problem-solving. To be included, learners had to be enrolled in Grade 1 during the study period, demonstrate a need for support in early numeracy, and attend classes regularly throughout the intervention. Learners who incurred prolonged absences or failed to complete either the pretest or posttest were excluded from the final analysis. Altogether, the study involved 360 learners ($N = 360$), with 180 assigned to the experimental group and 180 to the control group.

The resulting sample provided sufficient observations for the planned statistical analyses. Following conventional power analysis guidelines for independent-samples *t*-tests, a sample of this size offers adequate statistical power to detect medium-to-large intervention effects at the 0.05 level of significance (Kang, 2021). More importantly, drawing participants from twelve schools allowed the study to capture the diversity of classroom contexts within the district, thereby strengthening the basis for comparing the outcomes of manipulative-based instruction with those of conventional teaching.

Research Instrument

The study utilized a researcher-developed Early Numeracy Skills Test consisting of 40 items aligned with the Department of Education's Most Essential Learning Competencies (MELCs) for Grade 1 Mathematics. The instrument was designed to capture the range of foundational competencies expected at this level, including number recognition, counting, number sense, basic addition and subtraction, comparison of quantities, pattern recognition, and simple problem-solving. Recognizing that mathematical understanding in the early grades is closely tied to concrete experiences, the assessment incorporated age-appropriate multiple-choice items supported

by visual representations, number illustrations, and familiar situations that reflected learners' everyday experiences.

The instrument's development drew on established frameworks in early mathematics assessment that view conceptual understanding and procedural fluency as complementary dimensions of numeracy development (Fauzan, 2025). Accordingly, the items required learners not only to perform basic computations but also to understand numerical relationships, identify patterns, represent quantities, and apply simple mathematical ideas in meaningful contexts. Each correct response was assigned one point, and the resulting scores were interpreted using proficiency levels ranging from Very Low to Very High to support both descriptive and inferential analyses.

Before use in the study, the instrument underwent pilot testing with Grade 1 learners not included in the final sample. The pilot administration allowed the researchers to examine the clarity, appropriateness, and level of difficulty of the items. To strengthen content validity, a panel of experienced Grade 1 mathematics teachers and curriculum specialists also reviewed the instrument, evaluating its alignment with the MELCs and its suitability for young learners' developmental characteristics. Internal consistency was established through Cronbach's alpha, yielding a reliability coefficient of $\alpha = 0.88$, indicating that the instrument measured early numeracy skills with a high degree of consistency.

Data Gathering Procedure

Data collection began with the administration of the Early Numeracy Skills Test to all participating learners in order to establish their initial level of numeracy competence. The pretest served as the basis for determining whether the experimental and control groups were comparable before the intervention. Following the pretest, learners in the experimental group participated in a six-week program of manipulative-based mathematics instruction, while those in the control group continued with the conventional instructional practices ordinarily used in their classrooms, including teacher demonstrations, textbook-based lessons, seatwork, and worksheet exercises. The researchers monitored attendance and learner participation throughout the intervention to ensure both groups received consistent exposure to their respective instructional approaches. At the end of the intervention period, the same assessment was administered as a posttest, maintaining the original instrument's content, structure, and level of difficulty. The completed tests were subsequently coded, organized, and prepared for statistical analysis.

The intervention was conducted over six weeks, with three sessions each week lasting approximately 40 to 60 minutes. Although individual lessons varied according to the mathematical competency being taught, they generally followed a common instructional sequence that emphasized the gradual movement from concrete experiences to abstract understanding. Lessons began by introducing the target concept through manipulatives that activated learners' prior knowledge and sparked interest. This was followed by guided exploration, during which learners used concrete materials such as counters, blocks, number rods, and other age-appropriate resources to represent numbers, compare quantities, and perform basic mathematical operations with the teacher's guidance. The lesson concluded with application and reflection activities, where learners solved contextualized mathematical tasks using manipulatives before progressively translating these experiences into symbolic representations and written solutions.

Rather than serving as occasional teaching aids, manipulatives were integrated into every stage of instruction to support learners' developing understanding of mathematical concepts. Their use encouraged learners to examine relationships among numbers, test emerging ideas, and gradually connect concrete experiences with abstract mathematical representations. To ensure that the intervention was implemented as intended across all participating schools, periodic classroom observations and teacher implementation checklists were employed throughout the six-week period.

Data Analysis Procedure

The analysis began with descriptive statistics, including frequency, percentage, mean, and standard deviation, to summarize learners' accuracy scores and their distribution across the established proficiency levels. These measures offered a general picture of learners' performance before and after the intervention and served as the basis for subsequent inferential analyses.

To determine whether meaningful changes occurred within each group, paired-samples *t*-tests were performed on the pretest and posttest scores. Differences between the experimental and control groups were then examined using independent-samples *t*-tests based on their posttest performance. Beyond statistical significance, the magnitude of the observed differences was estimated through Cohen's *d*, with effect sizes interpreted as small (0.20), medium (0.50), or large (0.80) following Cohen's established guidelines.

Before conducting the inferential tests, the assumptions underlying parametric analysis were evaluated using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variances. The results indicated that these assumptions were satisfied, supporting the use of parametric procedures. In addition to total scores, analyses were conducted using percentage correct scores to facilitate interpretation across proficiency levels. All statistical analyses were carried out using Jamovi version 2.6.26, a free and open-source statistical software that requires no license or activation and is available for public download and use.

Ethical Considerations

The study was conducted with due regard for the rights, welfare, and dignity of the participating learners. Prior to data collection, informed consent was obtained from parents or legal guardians, while age-appropriate assent was secured from the learners themselves. Participation was entirely voluntary, and both learners and their parents were informed that they could withdraw from the study at any point without penalty or any effect on the learners' standing in school. Approval to conduct the study was likewise obtained from the appropriate school authorities and the Schools Division Office before the intervention was implemented.

Care was taken to protect the privacy of all participants throughout the research process. Learners were identified only through assigned codes, and all findings were presented in aggregate form to ensure that no individual learner or participating school could be identified. Electronic records were stored in password-protected devices, while printed documents were kept in a secure location accessible only to the researcher. Consistent with institutional research guidelines, the collected data will be retained for three years after the completion of the study and will thereafter be securely disposed of.

The intervention itself involved no foreseeable physical, psychological, or academic risk. Manipulative-based instruction is a developmentally appropriate approach that is routinely used in elementary mathematics classrooms and was integrated into regular classroom instruction without disrupting learners' educational experiences. Throughout the study, the researcher remained mindful of the dual responsibility as both educator and investigator by adhering to standardized procedures, documenting implementation consistently, and exercising impartiality in administering the intervention, scoring the assessments, and interpreting the findings.

Results and Discussion

As outlined in the research design, the analysis proceeded in three stages. It began by comparing the experimental and control groups' pretest scores to determine whether the groups were comparable before the intervention. The second stage examined changes within each group by comparing pretest and posttest scores, allowing determination of the extent of learners' progress over the course of the study. The final stage compared the two groups' post-intervention performance to determine whether manipulative-based instruction produced greater gains in early numeracy than conventional classroom instruction. Throughout the analysis, descriptive statistics, particularly frequency distributions, were presented alongside the corresponding inferential statistics from the *t*-tests. Taken together, these measures provided both a profile of learners' performance and a basis for determining whether the observed differences were statistically significant.

Baseline Data: Pretest Early Numeracy Skills of CG and EG

The researcher first assessed learners' early numeracy skills before the intervention by administering the researcher-developed Early Numeracy Skills Test to all participants ($N = 360$). The pretest results established the initial performance of both groups and provided the benchmark against which subsequent learning gains were evaluated. Table 1 summarizes the distribution of the pretest scores.

Table 1. *Pretest Early Numeracy Skills Scores of Control and Experimental Groups*

Score Range	Interpretation	Control Group		Experimental Group	
		f	%	f	%
33–40	Very High	0	0.00	0	0.00
25–32	High	28	15.5	30	16.6
17–24	Moderate	82	45.5	80	44.4
9–16	Low	58	32.2	56	31.1
0–8	Very Low	12	6.67	14	7.78

The pretest results suggest that the two groups entered the study on comparable footing. The similar score distributions indicate that neither group had a meaningful advantage before the intervention, providing a sound basis for examining whether subsequent differences could reasonably be attributed to the instructional approach rather than to pre-existing disparities. At the same time, the concentration of learners in the Low and Moderate proficiency levels suggests that although most learners had acquired the basics of early numeracy, many had yet to develop the deeper understanding needed to apply mathematical ideas with confidence. The absence of learners in the Very High category, along with the presence of those who remained at the Very Low level, underscores that foundational mathematical learning in the early grades remains uneven and that opportunities to strengthen these competencies are both necessary and timely.

This pattern resonates with a growing body of research on early mathematics learning. Shumway (2023) argued that young learners often acquire counting routines and number identification ahead of a more robust understanding of numerical relationships and operations. In other words, reciting numbers does not necessarily translate into understanding how numbers work. Rittle-Johnson & Siegler (2022) likewise distinguished procedural fluency from conceptual understanding, noting that children may perform familiar calculations correctly while still struggling to explain mathematical relationships or apply them in unfamiliar situations. Taken together, these studies suggest that early numeracy is not simply about getting the correct answer; it depends on helping learners build meaningful connections between concrete experiences and abstract mathematical ideas.

Table 2. *Independent-Samples t-Test for Pretest Early Numeracy Skills Scores*

Group	Mean	SD	<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Control Group	17.98	5.62	0.23	358	.818	0.02
Experimental Group	17.84	5.58				

To test significance, an independent-samples t-test was conducted. The results presented in Table 2 indicate that the experimental and control groups did not differ significantly in their pretest performance, $t(358) = 0.23$, $p = .818$. The negligible effect size (Cohen's $d = 0.02$) further suggests that any difference between the two groups was trivial in practical terms. These findings show that learners entered the study with comparable levels of early numeracy, providing a credible baseline for evaluating the intervention's effects. This baseline equivalence aligns with established practice in quasi-experimental research, where demonstrating that groups do not differ significantly before an intervention is essential for strengthening confidence in subsequent comparisons (Miller et al., 2020). Similar baseline-equivalence procedures have likewise been reported in manipulative-based mathematics interventions, including Muhammad et al. (2023), who confirmed that their experimental and control groups did not differ significantly prior to instruction before examining posttest differences. Because the groups were statistically equivalent before implementation, any posttest differences are more reasonably interpreted as outcomes of the instructional approach rather than consequences of pre-existing differences in learners' abilities.

Within-Group Comparison of Early Numeracy Skills Scores

Table 3 presents the distribution of scores within the control group (CG) and experimental group (EG). The descriptive results in Table 3 indicate that learners in both groups improved after the intervention period, although the extent of improvement differed. While the control group showed modest gains, the experimental group shifted more markedly toward higher proficiency levels, with most learners reaching the High and Very High categories by the posttest. Equally notable was the disappearance of learners in the Very Low category within the experimental group, whereas a small proportion of learners in the control group continued to perform at this level. Together, these patterns suggest that learning occurred under both instructional conditions, but improvement was more pronounced among learners who engaged with manipulative-based instruction.

Table 3. Within-Group Comparison of Early Numeracy Skills Scores (CG and EG)

Score Range	Interpretation	Control Group		Experimental Group	
		Pretest	Posttest	Pretest	Posttest
33–40	Very High	0 (0.00%)	8 (4.44%)	0 (0.00%)	62 (34.44%)
25–32	High	28 (15.56%)	45 (25.00%)	30 (16.67%)	74 (41.11%)
17–24	Moderate	82 (45.56%)	80 (44.44%)	80 (44.44%)	34 (18.89%)
9–16	Low	58 (32.22%)	42 (23.33%)	56 (31.11%)	10 (5.56%)
0–8	Very Low	12 (6.67%)	5 (2.78%)	14 (7.78%)	0 (0.00%)

Whether these observed differences reflected genuine intervention effects rather than chance variation was subsequently examined through paired-samples *t*-tests, the results of which are presented in Table 4.

Table 4. Paired-Samples *t*-Test for Within-Group Comparison

Group	Pretest Mean (SD)	Posttest Mean (SD)	<i>T</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Control Group	17.98 (5.62)	20.46 (6.18)	4.23	179	< .001	0.38
Experimental Group	17.84 (5.58)	29.34 (5.72)	20.15	179	< .001	1.50

The results showed that both groups made statistically significant gains over the course of the study. Although learners exposed to conventional instruction showed measurable progress, the experimental group's gains were considerably larger, as reflected in the substantial effect size (Cohen's *d* = 1.50) compared with the control group (Cohen's *d* = 0.38). This means that the observed improvement was not simply a consequence of continued classroom exposure or the passage of time. Rather, the instructional approach itself appears to have played a meaningful role in strengthening learners' early numeracy skills.

This interpretation is supported by previous work on mathematics learning in the early grades. Hurst & Linsell (2020) argued that manipulatives become effective not because they make lessons more engaging, but because they enable learners to construct mathematical meaning through direct interaction with concrete objects. Similarly, Sikhwari & Feza (2024) observed that conceptual understanding deepens when learners explore relationships and solve problems using tangible representations before relying solely on symbols. These findings further support these observations by suggesting that the benefits of manipulative-based instruction extend beyond isolated mathematical competencies to broader measures of early numeracy.

A plausible explanation for the substantial gains observed among learners in the experimental group lies in the progression from concrete experience to abstract reasoning that characterizes manipulative-based instruction. As Byrne et al. (2023) noted, physical manipulatives help learners develop mental representations of mathematical ideas that later support symbolic thinking. From this perspective, the large effect size is more than a statistical indicator; it reflects the educational value of allowing children to encounter mathematical concepts in ways that are visible, tangible, and meaningful. This reinforces the argument advanced by Flores et al. (2020) that early mathematics learning is strengthened when learners are given repeated opportunities to build understanding through concrete experiences before they are expected to operate at an abstract level.

Posttest Early Numeracy Skills of Control and Experimental Groups

Having established that both groups improved over the course of the intervention, the analysis turned to a more consequential question: whether learners exposed to manipulative-based instruction ultimately outperformed those who received conventional classroom instruction. Rather than focusing solely on individual progress, this comparison examined how much the intervention improved learning outcomes relative to existing practice. Table 5 presents the distribution of posttest scores for the two groups.

Table 5. Posttest Early Numeracy Skills Scores of Control and Experimental Groups

Score Range	Interpretation	Control Group		Experimental Group	
		Frequency	Percentage	Frequency	Percentage
33–40	Very High	8	4.44%	62	34.4%
25–32	High	45	25.0%	74	41.1%
17–24	Moderate	80	44.4%	34	18.8%
9–16	Low	42	23.3%	10	5.56%
0–8	Very Low	5	2.78%	0	0.00%

The posttest results reveal a noticeable divergence in the performance of the two groups. Although learners in both groups improved, their achievement was distributed quite differently. Most learners in the control group remained within the Low and Moderate proficiency levels, whereas the experimental group was concentrated in the High and Very High categories. Indeed, more than three-fourths (75.55%) of learners exposed to manipulative-based instruction attained High or Very High proficiency, compared with only 29.44% of those who received conventional instruction. This pattern suggests that the intervention did more than raise scores; it enabled a considerably larger proportion of learners to reach higher levels of numeracy competence. This distributional shift aligns with Sikhwari and Feza (2024), who reported that foundation-phase learners who engaged with manipulatives were better able to connect concrete experiences to abstract mathematical concepts, resulting in deeper conceptual understanding rather than surface-level procedural gains. This also aligns with Byrne et al. (2023), whose scoping review found that physical manipulatives tend to produce the strongest benefits when integrated purposefully into instruction rather than used as occasional aids, as in the present intervention. Whether this observed difference reflected a genuine effect of the instructional approach was subsequently examined through an independent-samples *t*-test, the results of which are presented in Table 6.

Table 6. Independent-Samples *t*-Test for Posttest Early Numeracy Skills Scores

Group	Mean	SD	<i>t</i>	<i>df</i>	<i>p</i>	Cohen's <i>d</i>
Control Group	20.46	6.18	14.21	358	< .001	1.50
Experimental Group	29.34	5.72				

The comparison of posttest scores yielded a clear result. Learners who participated in manipulative-based instruction performed significantly better than those who received conventional mathematics instruction, $t(358) = 14.21$, $p < .001$. The large effect size (Cohen's $d = 1.50$) further suggests that the difference was not merely a statistical artifact but one with meaningful educational implications. In practical terms, the intervention helped learners develop stronger early numeracy skills than routine classroom instruction alone would typically produce. This finding further supports a growing body of research that views learning mathematics as an active process of constructing meaning rather than simply acquiring procedures. Muhammad et al. (2023) have shown that manipulatives are most effective when they help learners make sense of numerical relationships through direct engagement with concrete materials. Their value lies not in the objects themselves but in the opportunities they create for learners to explore, question, and gradually internalize mathematical ideas. The present study reinforces this view. The substantial gains observed among learners in the experimental group suggest that when children first encounter mathematical concepts through concrete experiences, they can better build the conceptual foundations on which later mathematical thinking depends. This perspective is likewise reflected in the concrete-representational-abstract framework advanced by Clements and Sarama (2020), which emphasizes that abstract reasoning develops more meaningfully when grounded in tangible experiences.

The findings may also be understood from the standpoint of cognitive load. For young learners, abstract symbols and procedures can easily overwhelm working memory when introduced without adequate conceptual support. Manipulative materials help bridge this gap by making mathematical relationships visible and accessible, allowing learners to devote more attention to understanding rather than memorizing procedures (Gnawali, 2025). From this perspective, the experimental group's superior performance is not surprising. It reflects the advantage of an instructional approach that reduces unnecessary cognitive demands while encouraging learners to reason through mathematical ideas in concrete and meaningful ways.

In general, these results strengthen the earlier evidence from the within-group analyses. The gains observed among learners exposed to manipulative-based instruction cannot be explained solely by time, repeated exposure to the test, or routine classroom learning. Rather, they point to the instructional intervention itself as the more plausible source of improvement. Viewed alongside the consistently large effect sizes, the findings provide compelling evidence that manipulative-based instruction offers a more effective pathway for developing Grade 1 learners' foundational numeracy skills.

Conclusion

This study concludes that manipulative-based instruction was associated with significantly greater improvements in the early numeracy skills of Grade 1 learners than conventional mathematics instruction. Consistent with the

study objectives, both groups improved significantly from pretest to posttest, but the experimental group showed substantially greater gains, with a large effect size and a considerably larger proportion of learners reaching High or Very High proficiency than the control group. This suggests that manipulative-based instruction was associated with stronger early numeracy outcomes than conventional instruction. It is important to note that the findings of this study provide empirical evidence on constructivist perspectives on learning, the concrete-representational-abstract progression, and cognitive load theory, which collectively hold that young children build mathematical understanding more effectively when abstract ideas are first encountered through tangible materials (Clements & Sarama, 2020; Flores et al., 2020; Gnawali, 2025). They also affirm and extend existing studies on the benefits of purposeful manipulative use in early mathematics (Byrne et al., 2023; Muhammad et al., 2023; Sikhwari & Feza, 2024). Because schools were not randomly assigned, however, the findings are interpreted as evidence of association rather than proof of causation.

The results offer practical guidance for strengthening early numeracy instruction. For teachers, the findings support routinely integrating manipulatives into daily mathematics lessons rather than reserving them for occasional demonstrations. For curriculum developers and school leaders, the results suggest that concrete, learner-centered strategies deserve a central place in foundational mathematics instruction. For teacher education, the findings highlight the value of preparing both pre-service and in-service teachers to use manipulatives purposefully, with explicit attention to guiding learners from concrete experiences toward abstract understanding (Hurst & Linsell, 2020). These implications offer directions for continuous improvement rather than definitive prescriptions, given the study's methodological limitations.

Several limitations should be considered when interpreting the findings. First, purposive sampling was used, and schools were not randomly assigned to conditions; although schools were matched on key characteristics, unmeasured differences between groups may have influenced the results. Second, learners were nested within intact classes and schools, and the analyses treated individual learners as independent observations, which may have underestimated standard errors due to clustering. Third, school-, classroom-, and teacher-level factors such as teacher effectiveness, instructional resources, and socioeconomic conditions were not statistically controlled. Fourth, the same pretest and posttest instrument was used, which may have introduced testing effects despite the six-week interval. Fifth, the study did not administer a delayed posttest, so the durability of the gains remains unknown. Finally, the study was conducted in one district in La Union, Philippines, and its findings may not be generalizable to other contexts with different learner profiles, resources, or instructional conditions.

Future research should address these limitations by using randomized or cluster-randomized designs, multilevel analyses that account for learners nested within schools, and delayed posttests to examine the sustainability of gains. Replication across grade levels, regions, and mathematical domains would further clarify the conditions under which manipulative-based instruction is most effective. For policy and classroom implementation, the present findings support modest, evidence-aligned steps: encouraging teachers to integrate manipulatives into regular mathematics instruction, providing targeted professional development on their purposeful use, and ensuring that schools have access to basic, low-cost concrete learning materials.

Contributions of Authors

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Conflict of Interests

The researcher declares no conflict of interest.

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