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MANIPULATIVE MODEL UTILIZATION: UPSHOT IN THE PERFORMANCE OF SOLVING NORMAL DISTRIBUTION PROBLEMS

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ABSTRACT

This study examined the use of physical and pictorial manipulatives in improving college students' performance in solving normal distribution problems at Jose Rizal Memorial State University, Dipolog Campus. A quasi-experimental pretest–posttest design involving non-equivalent groups was employed using intact classes. The control group received traditional instruction, while the experimental group received instruction integrating physical and pictorial manipulatives. A researcher-made 50-item test, with a reported Kuder–Richardson Formula 20 coefficient of .89, measured achievement before and after four instructional sessions. A researcher-made test assessed students' performance in selected areas of normal distribution before and after the intervention. Data were summarized using means and standard deviations and analyzed using z-tests and t-tests to examine differences within and between groups. Results revealed no statistically significant difference between the groups' pretest performance, indicating comparable initial performance. Both groups demonstrated statistically significant improvements from pretest to posttest. Although the experimental group obtained a higher posttest mean and a larger descriptive gain, the overall difference in posttest performance between the groups was not statistically significant. These findings suggest that physical and pictorial manipulatives may support students' learning of normal distribution concepts, but their superiority over traditional instruction was not established. Teachers may consider incorporating these resources based on instructional objectives and learners' needs and may develop and implement an extension program for students. Further research should examine learning retention and the conditions under which manipulatives contribute to improved performance.

Keywords: *physical and pictorial manipulative models, manipulative model utilization, normal distribution, mathematics performance, mathematics teaching*

INTRODUCTION

Normal distribution requires students to connect numerical procedures, probability statements, and graphical representations. Physical and pictorial manipulatives can make these relationships visible during instruction. Furner and Worrell (2017) discuss the instructional value of manipulatives, while Monte (2021) explores their role in mathematics education. These contributions support examining how concrete and visual representations can assist college students with probability problems.

The value of manipulatives depends on their instructional use. Laski et al. (2015) identify principles for connecting materials with mathematical ideas rather than treating the objects themselves as the learning goal. Cockett and Kilgour (2015) report positive perceptions of engagement, understanding, efficiency, and enjoyment in a primary classroom. Kontaş (2016) examines achievement and attitudes among secondary students. These settings provide relevant precedents, although their findings cannot be assumed to apply directly to tertiary normal distribution instruction.

Byrne et al. (2023) synthesize interventions involving physical manipulatives and identify promising mathematics findings alongside variation in materials and activities. This variability supports studying particular concepts and learner groups. The present investigation focuses on college students studying normal distribution, where understanding regions under a curve is central to interpreting probabilities.

The instructional rationale connects physical action, pictorial representation, and symbolic problem solving. Mayer's (2020) cognitive theory of multimedia learning provides a complementary explanation of how words and graphics can support learning when relevant information is selected, organized, and integrated. This framework informs the use of representations; the present study did not directly measure cognitive processing.

Active participation provides a further instructional context. Wong and Liem (2022) clarify student engagement as a construct, and Qureshi et al. (2023) examine collaborative learning and engagement in relation to learning performance. Razak et al. (2022) review critical thinking through problem-based learning. These approaches are distinct from manipulative instruction, but they highlight the importance of meaningful tasks and learner participation. Engagement and critical thinking were not measured as outcomes in the present study.

The study compared traditional instruction with instruction using physical and pictorial normal-curve manipulatives during the second semester of Academic Year 2023–2024. Its contribution is a classroom-based comparison of performance before and

after instruction, interpreted with attention to the limitations of intact-class assignment and the available statistical records.

Research Questions

This study aimed to assess the effectiveness of manipulative model utilization in solving normal distribution problems by comparing the pretest, posttest, and mean gain performances of the control and experimental groups. Specifically, it sought to answer the following questions:

1. What is the pretest performance of the control and experimental groups?
2. Is there a significant difference between the groups' pretest performance?
3. What is the posttest performance of the control and experimental groups?
4. Is there a significant difference between the groups' posttest performance?
5. Is there a significant difference between pretest and posttest performance within each group?
6. Is there a significant difference in mean gains between the groups?

METHODOLOGY

The study employed a quasi-experimental pretest–posttest design with non-equivalent control and experimental groups at a state university campus in Dipolog City. The study period extended from January to May 2024, during the second semester of Academic Year 2023–2024. Convenience sampling selected two intact first-year Bachelor of Secondary Education classes enrolled in Mathematics of the Modern World. The classes comprised 93 students with varying ages and ability levels. Detailed demographic distributions were not recorded in the reported results. A coin toss assigned the intact classes to instructional conditions: 45 students formed the traditional-instruction control group, and 48 formed the experimental group. Students were not individually randomized.

A researcher-made, 50-item achievement test was developed from an initial pool of 60 items. Construction followed the course syllabus, learning objectives, a table of specifications, and Bloom's taxonomy. The test covered properties of standard normal distribution, areas below and above specified z-values, areas between z-values, and applications of normal distribution. Items provided multiple-choice responses, with instructions permitting a written answer when the correct answer was absent from the choices. The test assessed achievement rather than attitudes and did not use a Likert scale.

The adviser and subject-matter experts reviewed the test for content, appropriateness, and alignment with the table of specifications. Following revision, the instrument was pilot-tested with 41 students who had studied the topic and were not included in the main sample. Responses underwent item analysis and internal-consistency assessment. The author confirmed a Kuder–Richardson Formula 20

coefficient of .89. Overall mean scores were interpreted using the original categories: poor, 10.00 and below; fair, 10.01–20.00; good, 20.01–30.00; very good, 30.01–40.00; and outstanding, 40.01–50.00.

Institutional permission was obtained through the graduate school and relevant campus and college administrators. Participants received information on the research purpose and procedures, and consent was sought. The pretest was administered in March 2024, after the midterm examination and instrument validation. Instruction followed over two weeks, with four sessions totaling six instructional hours. Both groups addressed the same objectives and topics. Traditional instruction used explanations, worked examples, z-tables, and practice exercises. Experimental instruction incorporated physical and pictorial normal-curve models to represent areas and solve probability problems. Both lesson plans included group application activities. A posttest followed instruction, and scores were recorded for analysis.

Means and standard deviations summarized achievement by group, assessment occasion, and content area. The original methodology specified independent-samples t-tests for between-group comparisons and correlated-samples t-tests for within-group comparisons, with a significance level of .05. It also described z-tests against hypothetical benchmarks and use of Jamovi and Microsoft Excel.

The study was limited to two intact classes at one campus and a short instructional period. One class per condition prevents separation of treatment effects from class-specific influences. Convenience sampling limits generalizability.

The same achievement instrument was administered before and after instruction, so familiarity with the test may have contributed to improvement. The available record does not document delayed retention, transfer to unfamiliar tasks, intervention fidelity, or a measured engagement outcome. No item-level data or individual paired scores were supplied for this completion. Accordingly, statements about particular misconceptions, individual mastery, motivation, and causal mechanisms remain instructional interpretations rather than directly observed findings.

RESULTS

Tables 1–6 summarize the supplied results. Control and experimental sample sizes were 45 and 48, respectively.

Table 1: Pretest Performance of the Learners in the Control Group and Experimental Group

Group	No. of Items	HM	AM	SD	Z-Value	D
Control	50	37.5	20.18	4.33	-4.00	Good
Experimental	50	37.5	19.52	4.929	-3.65	Fair

Table 2: Test of Difference between the Control and Experimental Groups' Pretest Performance

Group	Mean	SD	t-computed	Decision
Control	20.18	4.327	0.67	Not Significant
Experimental	19.52	4.929		

Table 3: Posttest Performance of the Learners in the Control Group and Experimental Group

Group	No. of Items	HM	AM	SD	Z-Value	D
Control	50	37.5	28.11	7.367	-1.27	Good
Experimental	50	37.5	30.56	7.441	-0.93	Very Good

Table 4: Test of Difference between the Control and Experimental Groups' Posttest Performance

Group	Mean	SD	t-computed	Decision
Control	28.11	7.367	1.55	Not Significant
Experimental	30.56	7.441		

Table 5: Test of Difference between the Pretest and Posttest of the Students in the Control Group and Experimental Group in terms of Mathematical Test

Group	Pretest M (SD)	Posttest M (SD)	Decision
Control	20.18 (4.33)	28.11 (7.367)	Significant
Experimental	19.52 (4.929)	30.56 (7.441)	Significant

Table 6: Test of Difference on the Mean Gains between the Control and Experimental Group

Group	Mean Gain	Difference in Mean Gains	t-value	p-value	Decision
Control	7.93	3.11	2.15	.034	Significant
Experimental	11.04				

DISCUSSION

The pretest results (Table 1) indicate that both groups entered the intervention with relatively similar knowledge of normal distribution. The control group obtained a mean score of 20.18 (SD = 4.33), whereas the experimental group obtained 19.52 (SD = 4.929).

These scores were interpreted as good and fair, respectively, under the study's original score descriptions, although both means were near the boundary of those categories. The results suggest that many students had yet to develop secure competence in interpreting normal-curve areas and using standardized scores. Such a need for instruction is consistent with the rationale for connecting concrete, pictorial, and symbolic representations described by Laski et al. (2015) and Furner and Worrell (2017). The available summary scores, however, do not reveal which specific concepts or problem types presented difficulty.

Table 2 shows that the difference between the control and experimental groups' pretest means was not statistically significant (reported t = 0.67). This supports treating the groups as broadly comparable in initial assessed achievement, but a nonsignificant result does not prove that the two intact classes were identical. Pre-existing class differences may remain, especially because individual students were not randomly assigned. This baseline comparison therefore supports a cautious interpretation of subsequent group contrasts rather than eliminating selection concerns.

Following instruction, Table 3 shows that the control group reached a posttest mean of 28.11 (SD = 7.367), interpreted as good, while the experimental group reached 30.56 (SD = 7.441), interpreted as very good. The experimental group's higher mean is descriptively consistent with the possible contribution of physical and pictorial normal-curve models, which allow learners to visualize probability regions before working symbolically. This interpretation is compatible with Mayer's (2020) account of learning from words and graphics and with the instructional potential of manipulatives discussed by Monte (2021). Nevertheless, these ideas describe plausible mechanisms; understanding of representations and students' cognitive processing were not directly measured.

Table 4 reports that the difference in posttest performance between groups was not significant (reported t = 1.55). Although the experimental mean was higher by 2.45 points, the evidence does not establish a statistically reliable advantage in absolute posttest scores. This qualified finding is important because literature on manipulatives reports variation in learning outcomes and emphasizes that benefits depend on instructional implementation and context (Byrne et al., 2023; Laski et al., 2015). The absence of a significant posttest difference should not be interpreted as evidence that the two instructional approaches are equivalent.

Table 5 indicates significant pretest-to-posttest improvement within both groups. The control mean rose from 20.18 to 28.11, whereas the experimental mean increased from 19.52 to 30.56. The gains suggest that learners benefited from instruction regardless of delivery condition, while the larger increase in the experimental class is consistent with the value of combining hands-on and graphical approaches with practice. Kontaş (2016) similarly investigated mathematics performance with manipulative instruction, although that study involved younger students and cannot establish the mechanism in the present tertiary setting. The source table did not provide paired-test statistics or precise p values, so the reported decisions are retained without independently recalculating them.

Table 6 reports mean gains of 7.93 for the control group and 11.04 for the experimental group. The 3.11-point difference in gains was statistically significant (reported $t = 2.15$, $p = .034$). Thus, the experimental class exhibited greater measured improvement from its starting point, even though the groups' posttest means did not differ significantly in a separate test. These results address different comparisons and need not agree. However, the records do not provide individual change scores or sufficient details to verify the gain-score test or determine whether a baseline-adjusted analysis would lead to the same conclusion. Class-level confounding, test familiarity, and the brief intervention also limit causal attribution.

Taken together, the results provide qualified support for the integration of physical and pictorial manipulatives when teaching normal distribution. Research on primary classroom engagement (Cockett & Kilgour, 2015) and work on collaborative learning and student engagement (Qureshi et al., 2023; Wong & Liem, 2022) offer useful instructional context, but the present study assessed achievement only, not engagement. Likewise, Razak et al. (2022) discuss critical thinking in problem-based learning, a different intervention. Accordingly, claims about motivation, enjoyment, collaboration, and critical thinking must remain hypotheses for future investigation rather than findings of this study.

Conclusions

The control and experimental groups showed similar pretest achievement, and the reported independent-group pretest comparison was not statistically significant. This indicates comparable starting performance within the limits of the available measurements and the intact-class design.

Both groups attained higher posttest means, with the experimental group performing better descriptively and reaching the study's very good category while the control group remained in the good category. However, their posttest difference was not statistically significant; therefore, superiority of manipulative-supported instruction based on posttest scores was not established.

Both classes demonstrated statistically significant improvement between pretest and posttest. In addition, the experimental group showed a significantly larger mean gain than the control group, suggesting that manipulative-supported instruction was associated with greater improvement during the study period.

Overall, physical and pictorial manipulatives appear to be a potentially useful instructional supplement for solving normal distribution problems. The quasi-experimental design, one intact class per condition, short implementation, and absence of delayed testing limit the strength and generalizability of this conclusion.

Recommendations

Mathematics instructors may integrate physical models and pictorial normal-curve representations into lessons on standard scores, shaded areas, and probability

interpretation, while explicitly connecting each representation to symbols, equations, and z-tables. Manipulatives should supplement rather than automatically replace explanation, worked examples, and guided practice.

Teacher educators and curriculum planners may provide practical workshops and lesson-design opportunities that illustrate how to move from concrete demonstrations to drawings and symbolic problem solving. Instructional materials should be matched to learning objectives and evaluated using actual student work.

College of Teacher Education through its community extension services, may develop and implement an extension program for Senior High School students to strengthen their conceptual understanding and problem-solving skills in Statistics and Probability through the integration of physical and pictorial manipulative models, interactive learning activities, and real-life applications of normal distribution.

Future investigators should involve additional classes and institutions, assign multiple classes to each condition where feasible, examine baseline-adjusted outcomes, and report complete test statistics, confidence intervals, and effect sizes. Delayed posttests and transfer tasks would help determine whether any learning advantage persists or generalizes beyond practiced problems.

Further research may also measure conceptual understanding, engagement, and fidelity of implementation directly. Those outcomes were not assessed in this study and should not be inferred from the achievement results.

Compliance with Ethical Standards

The researcher adhered to established ethical standards throughout the conduct of the study. Institutional permission was secured from the appropriate authorities prior to data collection, and participants were provided with relevant information regarding the study's objectives, procedures, and purpose. Informed consent was sought before data gathering to ensure that participants understood the nature of their involvement. The researchers recognized the importance of voluntary participation, the right to withdraw at any time without penalty, and the protection of participants' identities and personal information. These safeguards, including consent and confidentiality procedures, should be verified against the original consent forms and research documentation. Data handling was guided by the principles of confidentiality and the provisions of Republic Act No. 10173, otherwise known as the Data Privacy Act of 2012. The participants' rights, dignity, privacy, and well-being were given due consideration throughout the research process. Furthermore, the researchers declared no conflict of interest in conducting the study. Academic integrity was upheld by strictly avoiding plagiarism, properly acknowledging relevant sources, and maintaining objectivity and impartiality in the analysis and interpretation of the findings. The results were intended exclusively for academic and research purposes. Any use of artificial intelligence (AI) tools in the preparation of the manuscript should be transparently disclosed, with the researchers retaining full responsibility for the accuracy, originality, and integrity of the research output.

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