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Research Paper

# Effectiveness of the Representation–Abstraction–Prompt Interpretation (RAP) Strategy in Statistics: A Quasi-Experimental Study among College Students in One State University

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**Abstract**

This study aimed to determine the effectiveness of Representation-Abstraction-prompt Interpretation (RAP) as a strategy in teaching Statistics among first-year college students. It used a quantitative approach and a quasi-experimental research design. The study's respondents were 50 first-year college students who took Mathematics in the Modern World. They were selected using a matching technique and divided into a comparison group and an experimental group. The research instrument was a standardized multiple-choice test to assess students' performance and the strategy's effectiveness. The findings revealed significant differences between pre- and post-intervention test scores for both the experimental and comparison groups, indicating that students improved their performance on both the standard and RAP strategies. This implies that students were able to develop their skills in solving problems involving Statistics. Moreover, learners who used the RAP strategy performed better because they were able to transform their basic knowledge into complex ideas by representing, generalizing, and interpreting concepts when learning Statistics. It was observed that students demonstrated their mathematical abilities when they learned through a sequential teaching strategy. Hence, they may engage in more concrete statistical tasks where they can provide meaningful solutions by applying their prior knowledge, representation-abstraction, and prompt interpretation.

**Keywords:** *Representation, Abstraction, Prompt-Interpretation, Statistics, Mathematics, Effectiveness*

## INTRODUCTION

Statistics and probability occupy a central place in the mathematics curriculum because they prepare learners to organize information, interpret data, and make evidence-based decisions in academic and real-world settings. However, statistics remains difficult for many students, not mainly because they cannot compute, but because they struggle to connect ideas, represent problems meaningfully, and interpret results in context. Recent work in statistics education reports that college students persistently find statistics courses difficult and suggests that one contributing factor is the highly abstract nature of many statistical ideas (Silva & Sarnecka, 2025). Other recent studies likewise show that students struggle to represent mathematical ideas in symbolic, visual, and verbal forms, as well as to develop conceptual understanding and solve problems in statistics.

The instructional problem is therefore not simply a lack of practice; rather, many teaching approaches still emphasize procedures, calculation, or teacher-led explanation without fully developing the representational and interpretive skills that statistics requires. Dahlstrom-Hakki & Wallace (2022) revealed that students with mathematics difficulties recommend explicitly teaching vocabulary, guiding students through the statistical investigation process, and building understanding of variability, while intervention studies in statistics continue to show that approaches centered on discourse, context, or structured instructional support can improve conceptual understanding more effectively than traditional instruction. Even so, these approaches do not always organize learning around the full progression from representation to abstraction to interpretation, leaving a gap in how statistics is taught (Sutherland et al., 2022).


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Representation–Abstraction–Prompt interpretation (RAP) is a distinct contribution because it targets that progression directly. It is not just another classroom technique; it is a structured pedagogical sequence that moves students from concrete or visual representations to the abstraction of the underlying statistical idea, and then to a prompt interpretation of the result. In that sense, RAP addresses the conceptual disconnect that continues to limit students' understanding of statistics and offers a more focused approach to the subject's specific cognitive demands. Recent instructional studies in statistics support the value of approaches that foreground interpretation, context, and conceptual understanding. However, the literature still leaves room for a strategy that explicitly links representation, abstraction, and meaning-making in one sequence (Andam et al., 2025).

This study examined the effectiveness of RAP in teaching statistics to first-year college students and assessed its impact on their mathematical competence and readiness for advanced mathematics.

**Specific Objectives:**

1. Determine the pre-intervention and post-intervention mean scores of the student-respondents in both the comparison and experimental groups.
2. Examine whether there is a significant difference between the pre-intervention mean scores of the comparison and experimental groups.
3. Investigate whether there is a significant difference between the post-intervention mean scores of the comparison and experimental groups.
4. Analyze whether there is a significant difference between the pre-intervention and post-intervention mean scores within each group.

## LITERATURE REVIEW

Statistics and probability have become central to mathematics education because learners need to interpret data, reason with uncertainty, and make evidence-based decisions in academic and real-world contexts. Despite its importance, statistics remains a persistent difficulty for many students. Recent work in statistics education reports that college students still find statistics courses difficult and suggests that one major reason is the highly abstract nature of statistical ideas.

Studies of struggling learners likewise show that students often have difficulty representing mathematical ideas in symbolic, visual, and verbal forms, while broader reviews of mathematics learning point to conceptual barriers, ineffective teaching methods, and anxiety as recurring obstacles (Silva & Sarnecka, 2025). In statistics specifically, the problem is not only computation; students also struggle to choose appropriate procedures, connect results to context, and explain what the data mean (Mangarin & Caballes, 2024)

This pattern shows that the central issue in statistics learning is a gap between procedural performance and conceptual understanding. Students may complete formulas correctly yet still fail to construct a meaningful representation of the problem or interpret the answer in relation to the context. Recent instructional studies suggest that strategies that explicitly guide students through vocabulary, the statistical investigation process, and variability can support understanding more effectively than approaches that remain mostly procedural (Sutherland et al., 2022).

Similarly, intervention studies in probability and statistics show that discourse-based instruction can improve conceptual and procedural understanding more than traditional teaching. In contrast, work on statistics pedagogy for struggling students emphasizes visual and conceptual supports rather than formula-first instruction (Yimam & Kelkay, 2022). The unresolved question is how to organize instruction so that students move from seeing a statistical situation to abstracting the relevant concept to interpreting the result as meaningful evidence.

RAP addresses that gap as a structured conceptual model. It is not simply a sequence of teaching activities; it is a learning pathway built around three connected cognitive moves. First, Representation helps students externalize a statistical situation through graphs, tables, symbols, concrete examples, or other visual forms. This step reduces the cognitive load of the abstract idea and makes relationships visible. Second, Abstraction guides students to strip away surface features and identify the underlying statistical principle, such as variability, central tendency, or comparison. Third, Prompt interpretation requires students to explain what the abstracted result means in context, so knowledge is not left as a symbolic manipulation but becomes usable understanding. In this model, representation supports access, abstraction supports conceptual generalization, and interpretation supports transfer and justification.

Statistics today requires the ability to examine facts and ideas, generalize, explain, give reasons, theorize, and draw conclusions to complete statistical and probability questions (Puspitasari et al., 2019). However, students still have difficulties with combinatorial reasoning, probabilistic reasoning, and proving the variability of random variables, all of which relate to students' ability to apply logical thinking. Compared with other fields of study and research, statistics education is still a relatively new and developing field. The logic of RAP aligns with recent statistics education research, which consistently favors approaches that make meaning visible, connect concepts to context, and support students in reasoning about data rather than only computing with it.

A recent study on story-based tasks in undergraduate statistics found that interactive, contextualized tasks can support understanding at several levels, though achieving deeper understanding remains difficult without structured guidance (Lemieux & Chapman, 2024). Work on visual and conceptual instruction in statistics similarly shows that students benefit when teaching makes the underlying concept explicit and when visual representations are used to bridge from concrete examples to abstract ideas. RAP can therefore be understood as a pedagogical sequence that organizes these elements into one coherent model, with the explicit aim of turning statistical content into interpretable knowledge.

Conceptually, RAP can be represented as: Statistical situation or task to Representation, then Abstraction, Prompt interpretation, and Mathematical competence in statistics. This framework assumes that learning improves when students are first given a form they can see or manipulate, then guided to extract the relevant concept, and finally required to interpret the result in words and context. The mechanism matters because each phase addresses a different source of difficulty.

Representation addresses the problem of inaccessible abstraction; abstraction addresses the problem of fragmented or surface-level understanding; and interpretation addresses the problem of knowing a formula without knowing what it means. Taken together, these steps are expected to strengthen conceptual understanding, procedural choice, and transfer to new statistical problems. Accordingly, this study uses RAP as a teaching strategy for teaching statistics to first-year college students. It examines whether this progression improves mathematical competence more effectively than instruction that does not explicitly connect representation, abstraction, and interpretation.

## RESEARCH METHOD

### Research Design

This study employed a quantitative quasi-experimental research design to determine the effectiveness of Representation – Abstraction – Prompt interpretation (RAP) as a teaching strategy for teaching Statistics among 1st-year college students. The quasi-experimental research design was used to estimate the effects of the treatment, which requires comparing treatments across different conditions. Reichardt (2019) emphasized that quasi-experiments often involve comparing a treatment and a no-treatment condition.

For example, comparisons may be drawn between an innovative treatment and a usual standard-of-care treatment. Differences between the assigned groups will determine whether the intervention or treatment has a significant effect on participants. Moreover, a quasi-experimental design is appropriate for the study, as it aims to assess differences between the assigned groups. This type of experimental research design involves non-random assignment of participants because it requires using existing classes in the sample.

**Participants and Sampling**

The respondents of the study consisted of fifty (50) first-year college students enrolled at Laguna State Polytechnic University – Los Baños Campus. These students were from the College of Teacher Education and were currently taking the subject Mathematics in the Modern World, which includes Statistics as a core component. All participants had previously completed the Statistics and Probability course during their senior high school, indicating prior exposure to fundamental statistical concepts and skills necessary for engaging in more advanced statistical learning tasks.

From an initial pool of sixty-four (64) students, a total of fifty (50) participants were selected for inclusion in the study. In contrast, the remaining fourteen (14) students were treated as non-participating (blind) respondents to minimize potential contamination and ensure controlled group comparisons. The final sample was equally divided into two groups: twenty-five (25) students in the experimental group and twenty-five (25) students in the comparison group.

This study employed a non-probability sampling technique, specifically matched-pairing (pair-matching), to ensure comparability between groups. Participants were purposively selected and matched based on their pretest scores, arranged from lowest to highest. Each participant in the experimental group was paired with a counterpart in the comparison group who had a closely similar pretest score. This procedure was undertaken to establish baseline equivalence between groups, thereby reducing selection bias and controlling for initial differences in statistical ability.

After the matching process, only the best-matched pairs (n = 25 per group) were retained as official participants in the study. Students who could not be adequately matched due to discrepancies in pretest scores were categorized as blind participants and excluded from the main analysis. This approach strengthens the internal validity of the study by ensuring that any observed differences in posttest performance can be more confidently attributed to the intervention rather than pre-existing differences between groups.

**Table 1.** Participants of the Study

| Group | N | Selected Participants | Blind Participants |
|---|---|---|---|
| Comparison Group | 34 | 25 | 9 |
| Experimental Group | 30 | 25 | 5 |
| Total | 64 | 50 | 14 |

As shown in Table 1, an equal number of participants (n = 25) were assigned to both the experimental and comparison groups following the matched-pairing procedure, thereby ensuring group equivalence in terms of initial performance. The exclusion of unmatched participants further ensured the rigor of the comparison.

**Instrument**

A researcher-developed questionnaire was used as the main instrument for this study. It was used to gather primary data needed to analyze the effectiveness of RAP as a teaching strategy for statistics. This instrument consisted of a 25-item standardized test that assessed participants' achievement of learning competencies in Statistics and Probability, specifically Random Variables and Probability Distributions. It was used as an instrument in both the pre-intervention and post-intervention tests among the participants.

Moreover, before the instrument was implemented, it underwent reliability testing via pilot testing, yielding a reliable index with Cronbach's Alpha ($\alpha = 0.842$), indicating good internal consistency among the test items. Validation was conducted to assess the dependability and consistency of the data-gathering tool in producing reliable results when administered to the study's intended participants. Five (5) research experts assessed it using the criteria of Clarity, Overlapping Responses, Application, and Relationship to the Problem.

**Data Collection**

The preintervention assessment was given to the participants after the instrument was validated and approved by five (5) experts, and the research adviser and the associate dean of the college of teacher education signed and approved the request letter to include their students as respondents in the study. Ethical guidelines were strictly followed to ensure the confidentiality of the data and the well-being of the respondents.

Upon obtaining the preintervention test results, the researcher began applying RAP as the teaching strategy for the experimental group while continuing to use the usual standard teaching strategy for the comparison group. The treatment was implemented for three (3) weeks, which was equivalent to the time allotted for the discussion of the 2nd chapter of GEC 104, Statistics. After implementing the teaching strategy, the researcher administered the post-intervention test to the participants to assess the treatment's effectiveness.

After retrieving all the questionnaires, the researcher used the computer program, Excel spreadsheet, to tally and tabulate the data. The data underwent normality testing with the Shapiro-Wilk test, which indicated normality ($p = .073$), and were then analyzed with parametric tests. The researcher then presented, analyzed, and interpreted the results from the tabulated data using SPSS to address the research questions posed in the study.

**FINDINGS AND DISCUSSION**

This addresses the presentation of data, its analysis, and the interpretation of the effects of Representation-Abstraction-Prompt Interpretation (RAP) as a strategy for teaching mathematics. Table 2 shows the demographic profile of the respondents in the experimental and comparison groups.

**Table 2.** Demographic Profile of the Respondents

| Group | Demographic Profile | | Frequency | Percentage |
|---|---|---|---|---|
| Experimental | Sex | Male | 12 | 48.00% |
| | | Female | 13 | 52.00% |
| | Strand Graduated | STEM | 7 | 28.00% |
| | | HUMSS | 3 | 12.00% |
| | | ABM | 6 | 24.00% |
| | | GAS | 9 | 36.00% |
| Comparison | Sex | Male | 10 | 40.00% |
| | | Female | 15 | 60.00% |
| | Strand Graduated | STEM | 7 | 28.00% |
| | | HUMSS | 5 | 20.00% |

| | | | |
|---|---|---|---|
| | ABM | 8 | 32.00% |
| | GAS | 5 | 20.00% |

As shown in the table, the respondents in the experimental group were mostly female (52%, n = 13), and many had graduated from the GAS strand (36.00%, n = 9). On the other hand, most of the comparison group graduated in the ABM Strand (32.00%, n = 8) and were mostly female (60.00%, n = 8). This suggests that the study's findings are more reflective of female learners' characteristics and responses. Additionally, the variation in strand distribution between the experimental and comparison groups highlights differences in academic preparation that could contribute to observed differences in outcomes. Hence, these demographic characteristics should be considered when interpreting the results, as they may interact with the intervention's effectiveness or the measured variables.

**Table 3.** Pre-Intervention Test Mean Scores in Statistics Among the Students-Respondents in the Two Groups

| Group (n = 50) | Mean | Std. Dev. | Descriptive Interpretation |
|---|---|---|---|
| Experimental Group | 11.12 | 4.50 | Low |
| Comparison Group | 11.12 | 4.50 | Low |

Legend: 26– 30 = Very High; 21 – 25 = High; 16 – 20= Average; 11-15 – Low; 1 – 10 = Very Low

Table 3 presents the pre-intervention mean test scores of the respondents in Statistics. As presented in Table 3, both the experimental group and the comparison group (M = 11.12, SD = 4.50) demonstrated low baseline performance in statistics. Prior to conducting inferential analysis, tests of homogeneity of variances (Levene's test) were performed and indicated that the assumptions for parametric testing were satisfied ($p > .05$). However, an independent samples t-test revealed a statistically significant difference between groups at baseline ($p < .05$), indicating non-equivalence prior to intervention.

This baseline inequality suggests that subsequent comparisons must be interpreted with caution and statistically adjusted to control for initial group differences (Satsangi et al., 2019). Conceptually, the low performance in both groups may reflect insufficient prior knowledge in foundational mathematics, which is critical for statistical reasoning. This supports the assertion that prior mathematical competence influences performance in statistics. From a theoretical standpoint, the RAP framework emphasizes structured cognitive scaffolding beginning with representation; however, such scaffolding presupposes minimal prior knowledge, which appears limited among participants.

**Table 4.** Post-Intervention Test Mean Scores in Statistics Among the Students-Respondents in the Two Groups

| Group (n = 25) | Mean | Std. Dev. | Descriptive Interpretation |
|---|---|---|---|
| Experimental Group | 19.12 | 5.76 | Average |
| Comparison Group | 13.28 | 4.07 | Low |

Legend: 26– 30 = Very High; 21 – 25 = High; 11 – 20 = Average; 1 – 10 = Low

Table 4 presents the post-intervention mean test scores of the respondents in Statistics. As shown in Table 4, the experimental group has a mean score of 19.12 (SD = 5.76). On the contrary, the comparison group still shows low performance on the post-intervention test, with a mean of

13.28 (SD = 4.07). Based on these results, it is evident that both groups performed better than their pre-intervention scores.

When interpreted with caution, the higher adjusted mean for the experimental group suggests that the RAP strategy may contribute to improved statistical performance. Theoretically, RAP facilitates learning through progressive cognitive processing, representation, abstraction, and prompt interpretation, which aligns with constructivist principles that support deeper conceptual understanding. Thus, the observed improvement may reflect enhanced cognitive engagement rather than mere exposure to instruction.

Rodríguez-Muñiz et al. (2022) stated that distinct cognitive processes arising from differences between mathematics and statistics as academic disciplines have limited research on how students' prior achievement in mathematics influences their performance in college-level statistics. Nevertheless, students' capacity to draw on prior learning experiences facilitates their understanding of complex concepts required in advanced mathematical and statistical studies.

**Table 5.** Test Of Significant Difference Between the Posttest Mean Scores In Statistics of the Students in the Two Groups

| Test | Group | Mean | Mean Difference | t-value | p-value | Cohen's d |
|---|---|---|---|---|---|---|
| Post test | Experimental | 19.12 | 5.84 | 4.134** | .000 | 1.17 |
| | Comparison | 13.28 | | | | (Very Large) |

df = 48; ** Significant at .01 level; Cohen's d: small (d = 0.2), medium (d = 0.5), large (d = 0.8), very large (1.20), and huge (2.0)

Table 5 presents the test for significant differences in the post-intervention mean scores between the two student groups. As shown in Table 3, the posttest mean scores between the two groups differ significantly [$t(48) = 4.134$, $p < .01$] and indicate a very large effect size ($d = 1.17$). This means that the performance of the two groups was greatly affected by the teaching strategy that was used. In this study, the RAP serves as an intervention as an alternative to the standard teaching strategy among college students.

It allows learners in the experimental group to demonstrate higher performance in statistics, as they can make predictions about real-world events by comparing their results with those of others who applied the same broad principle of learning. Theoretically, RAP facilitates learning through progressive cognitive processing, representation, abstraction, and prompt interpretation, which aligns with constructivist principles that support deeper conceptual understanding.

Representation, abstraction, and interpretation allow learners to comprehend the underlying abstract premise of their thoughts. Yang (2017) found that students' overall perceptions of learning and satisfaction with the subject matter were influenced by their experiences with different teaching strategies.

**Table 6.** Test Of the Significant Difference Between the Pretest and Posttest Mean Scores in Mathematics of the Students in Each Group

| Group | Test | Mean | p-value | t-value | Cohen's d |
|---|---|---|---|---|---|
| Comparison | Posttest | 11.12 | .002 | 3.430** | 0.50 |
| | Pretest | 13.28 | | | (Medium) |
| Experimental | Posttest | 15.96 | .001 | 3.692** | 0.51 |
| | Pretest | 15.45 | | | (Medium) |

df = 24; ** Significant at .01 level; Cohen's d: small (d = 0.2), medium (d = 0.5), large (d = 0.8), very large (1.20), and huge (2.0)

Table 6 presents the test for significant differences between the pretest and posttest mean mathematics scores of the students in each group. As shown in Table 5, the pre-intervention and post-intervention test of the experimental ($t(24) = 3.692$, $p < .01$) and comparison group ($t(24) = 3.430$, $p < .01$) shows a statistically significant difference, since the computed p-value is less than .05. This indicates that the teaching strategy applied to both groups was effective for them.

However, the computed t-value also indicates that learners in the experimental group perform better. This shows that RAP, as a teaching strategy in Statistics, enables learners to develop their mathematical performance by applying basic concepts to learn more complex ideas in higher statistics. While these results indicate that learning gains occurred in both groups, they should not be interpreted as evidence of intervention effectiveness in isolation, as improvements may be attributable to general instructional exposure, practice effects, or maturation.

This relates to the findings of Dong et al. (2022), who emphasized that representation serves as a tool for communication and manipulation in the conceptual understanding of mathematical ideas. When students can represent a mathematical situation in a meaningful way, they see it as more accessible. Therefore, instructional strategies such as RAP should focus on allowing the students to learn through representations so they can generalize ideas and finally interpret them.

## CONCLUSIONS

The study found a statistically significant difference in pre-intervention scores between the experimental and comparison groups, indicating they were not equivalent at baseline. In addition, both groups demonstrated significant improvements from pretest to posttest, suggesting that learning gains occurred over the course of instruction. A statistically significant difference was also observed in the post-intervention scores, with a large effect size favoring the experimental group. However, these results should be interpreted with caution, as the initial group differences may have influenced the outcomes, thereby limiting direct causal interpretation.

From an interpretative standpoint, the improvements observed in both groups may be attributed to general instructional exposure, practice, or adaptation to the learning environment rather than the teaching strategy alone. While the experimental group achieved higher posttest performance, this does not conclusively establish the effectiveness of the Representation–Abstraction–Prompt Interpretation (RAP) strategy, given the quasi-experimental design and baseline inequality. Instead, the findings suggest a possible association between the use of RAP and enhanced student performance in statistics, particularly in facilitating engagement with increasingly complex concepts.

The study contributes theoretically by supporting the RAP framework as a structured approach that aligns with constructivist principles of learning, emphasizing progression from concrete representation to abstraction and interpretation. This implies that scaffolded instructional strategies may help learners develop a deeper conceptual understanding of statistics. Practically, the results suggest that educators may benefit from integrating RAP-based activities that promote visualization, generalization, and interpretation of statistical ideas. Nevertheless, the conclusions drawn remain tentative, and further research employing more rigorous designs and statistical controls is recommended to validate these findings.

## LIMITATION & FURTHER RESEARCH

This study has several limitations that should be carefully considered in interpreting the findings. The use of a quasi-experimental design with non-random assignment resulted in a statistically significant baseline difference between the experimental and comparison groups, which constitutes a threat to internal validity. This lack of group equivalence limits the ability to attribute observed differences in post-intervention outcomes solely to the intervention.

Consequently, the findings should be interpreted as associational rather than causal, as pre-existing differences may have influenced the results. In addition, the study involved a relatively small sample of sixty first-year college students from a single institution, thereby restricting the generalizability of the findings. The short duration of the intervention (three weeks) and the reliance on a 25-item achievement test as the primary performance measure further constrain the depth and stability of the conclusions.

Future research may address these limitations by employing more rigorous experimental designs, particularly those involving random assignment, to strengthen internal validity and support causal inference. Increasing the sample size and including participants from multiple institutions would enhance the external validity of the findings. Extending the duration of the intervention may also provide insights into the sustained effects of the Representation–Abstraction–Prompt Interpretation (RAP) strategy. Moreover, incorporating additional variables such as students' motivation, attitudes, and statistical reasoning, alongside multiple assessment measures, would allow for a more comprehensive and theoretically grounded evaluation of the strategy's role in mathematics and statistics instruction.

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