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Visualizing the P-Value: A Geogebra-Based Approach to Hypothesis Testing

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Abstract **Review Article**

In the present time, students learn mathematics in an active and meaningful way if technology is integrated into the instruction. This study explored how the use of GeoGebra-supported Technology-enhanced instruction (TEI) affects the hypothesis testing performance of Grade 11 STEM students at Diffun National High School. Using a quasi-experimental design, 89 STEM students were divided into two groups: one acted as an experimental group (GeoGebra Group) who were exposed to the Traditional teaching method combined with GeoGebra-supported TEI, and a control group (Traditional Group) who were taught using the Traditional teaching method only. The results revealed that after the intervention, both groups exhibited improved performance in hypothesis testing, but the GeoGebra group showed better performance as evidenced by the group's significantly higher posttest scores and greater mean gain. A moderate impact on students' learning outcomes was also shown, as indicated by the computed effect size (d = 0.517). In light of these findings, it is evident that incorporating GeoGebra in mathematics instruction can beneficially increase students' understanding of hypothesis testing and support improved academic performance.

Keywords: GeoGebra, Technology-enhanced Instruction, Hypothesis Testing, Statistics, Quasi-experimental design.

Introduction

The development of students' ability to think critically, interpret data, and make sound decisions is rooted in recognizing their way of learning mathematics. Rossman & Delmas (2022) mentioned that students often strive to grasp the abstract concepts in Statistics, specifically hypothesis testing, such as p-values, sampling distributions, and decision-making processes, which lead them to rely more on memorization than real comprehension.

Present teaching approaches take on active, learner-centered instructional strategies based in educational psychology and cognitive science to address these issues (Sanchez, 2023). Haleem et al. (2022) also indicated that by means of technology-enhanced instruction, students can manage variables and understand tangled information interactively and visually. GeoGebra, according to Ziatdinov & Valles Jr. (2022) is one of the technological tools that support this approach. It supports students' conceptual understanding of mathematical concepts through its visualization features and real-time variable manipulation. Gleaned from the constructivist theory, students can explore concepts visually, experimentally, and conceptually using GeoGebra, stressing learning through hands-on participation and experience (Matsha, 2025). However, popular use of traditional teaching methods in the Philippines limits GeoGebra's potential despite its benefits to mathematics instruction. Thus, this research aimed to evaluate the effectiveness of GeoGebra-supported Technology-enhanced Instruction in enhancing the hypothesis testing performance of Grade 11 STEM students at Diffun National High School for the SY 2025-2026.

Methodology

This study utilized a non-equivalent pretest-posttest quasi-experimental research design to evaluate the effectiveness of GeoGebra-supported technology-enhanced instruction (TEI). The participants were 89 Grade 11 STEM students from two intact classes at Diffun National High School for the school year 2025-2026 and went through a homogeneity of grouping test using a standardized diagnostic test in statistics (Levene’s test = 1.666, p = 0.200), consisting of 44 students in the Experimental Group (GeoGebra Group) and 45 students in the Control Group (Traditional Group). Purposive sampling was applied to select the participants. The study went through three weeks, during which both groups passed through the pretesting phase to ascertain their baseline proficiency in statistics. During the intervention phase, the Traditional Group was exposed to the traditional lecture method alone, while the GeoGebra Group received the traditional teaching method combined with GeoGebra-supported TEI, wherein they had lessons enhanced with GeoGebra and its functionalities.

The researcher utilized a 25-item teacher-made multiple-choice test in hypothesis testing, validated by experts for content, test format, organization, clarity, and language use, and reliability, as the main source of data collection. was administered as a pretest and posttest to assess the performance of the students in hypothesis testing. The data collected were organized and analyzed using mean, standard deviation, independent samples t-test, Levene’s test for equality of variances, Shapiro-Wilk test for normality, and Cohen’s d. Ethical standards were observed throughout the experimental period, that is, by seeking informed consent from the participants and ensuring the confidentiality of all collected data.

Results and Discussions

Table 1. Pretest Mean Percent Score in Hypothesis Testing of the Participants

Group	N	Mean Percent Score	SD	t	p-value	Decision
GeoGebra Group	44	73.05	4.30	0.069	0.945	Fail to reject Ho
Traditional Group	45	72.98	4.97			

p-value ≤ 0.05 *is significant*

The pretest mean scores showed that the initial understanding of hypothesis testing among the GeoGebra Group and the Traditional Group is comparable (t = 0.069, p = 0.945), with the GeoGebra Group mean of 73.05 (SD = 4.30) and the Traditional Group mean of 72.98 (SD = 4.97) in testing hypotheses, indicating that the mean difference is not statistically significant. The result supports the observed homogenous grouping, implying that any observed differences in posttest performance can then be attributed to the GeoGebra-supported TEI rather than pre-existing differences, emphasizing the study's internal validity as confirmed by the baseline equality.

Table 2. Posttest Mean Percent Score in Hypothesis Testing of the Participants

Group	N	Mean Percent Score	SD	t	p-value	Decision
GeoGebra Group	44	92.32	3.81	2.970	0.039	Reject Ho
Traditional Group	45	89.91	3.84			

p-value ≤ 0.05 *is significant*

The analysis of the independent samples t-test in the posttest mean score performances of the two groups reveals a statistically significant result, t = 2.970, p = 0.039, indicating that participants in the GeoGebra group performed better with an average score of 92.32 (SD = 3.81) compared to the 89.91 (SD = 0.84) average score of the traditional group in hypothesis testing. This suggests that GeoGebra-supported TEI is more effective than traditional methods in improving performance in hypothesis testing. This result is aligned with the findings of Haleem et al. (2022), indicating that the benefit of using technology in teaching abstract and computation-heavy subjects like statistics can be linked to this improvement. Ziatdinoy & Valles Jr. (2022) mentioned GeoGebra's visualizations as an aid to students' understanding of distributions, graphs, and variable relationships, while its interactive features promote hands-on exploration and engagement. Within the local framework, the same benefits have been recorded. Recto (2025) noted enhanced students' understanding and motivation in functions and graphs through GeoGebra-based instruction, while Picaza et al. (2024) revealed improved mathematics achievement among college students and increased achievement and engagement in solid geometry, as stated by Espinosa et al. (2026). Students also reported that proficiency with GeoGebra facilitated a clearer understanding of mathematics tasks, according to Negros et al. (2024). Overall, GeoGebra-supported TEI in teaching statistics supports both conceptual and procedural understanding in mathematics.

Table 3. Comparison of the Mean Difference of the Posttest and Pretest Hypothesis Testing of the Participants

Group	Posttest	Pretest	Mean Gain	SD	t	p-value	Cohen's d	Decision
GeoGebra Group	92.32	73.05	19.27	3.93	2.438	0.017	0.517	Reject Ho
Traditional Group	89.91	72.98	16.93	5.04				

p-value ≤ 0.05 *is significant*

The comparison of the mean gain scores between the two experimental groups reveals a statistically significant difference, t = 2.438, p = 0.017, showing that the GeoGebra group attained a higher mean gain (19.27, SD = 3.93) than the Traditional group (16.93, SD = 5.04). This implies that those who were exposed to the GeoGebra-supported TEI approach gained significant improvement in hypothesis testing compared to those who were taught using traditional instruction. This confirms that the higher mean gain obtained by the GeoGebra Group can be attributed to the effectiveness of the instructional approach and not due to chance. These findings are consistent with earlier studies highlighting the effectiveness of GeoGebra in associating abstract concepts with visual representations (Seftiana et al., 2024), Izdahara & Irvan (2025) also mentioned the promotion of exploration and engagement, and enabling students to observe statistical processes such as test statistics and sampling variation in action (Ziatdinov & Valles Jr., 2022). Moreover, Amedu and Hollebrands (2022) reported that teachers view technology as a valuable tool for fostering interactive learning and increasing students' engagement, which supports deeper conceptual understanding. Interactive visualization is more effective than traditional methods in improving understanding and retention, as evidenced by local classroom set-ups. Generally, as compared to the traditional teaching method alone, greater gains in hypothesis testing showed through conceptual understanding, active participation, and performance were the result of integrating GeoGebra-supported TEI with the traditional teaching method.

The results also demonstrate the practical significance of GeoGebra-supported technology-enhanced instruction, as indicated by the computed Cohen's d of 0.517, which reflects a moderate and educationally meaningful effect; this suggests that the use of GeoGebra's visual, interactive, and exploratory features helped students better understand abstract concepts, use statistical procedures confidently, and achieve improved performance.

The higher gains of the GeoGebra group agree with recent studies that feature the advantage of using interactive digital tools in learning mathematics and statistics. In particular, Gurmu (2024) found that students who were taught with the integration of GeoGebra showed better grasp of geometry concepts than those taught using traditional teaching methods alone. Moreover, Radovic (2024) also highlights the importance of interactive tools in developing critical thinking, emphasizing that technology integration in mathematics instruction fosters active engagement and deeper understanding. In the same way, Ardina and Boholano (2025) reported that students exposed to GeoGebra performed better and retained mathematical concepts longer than those in conventional classes. Putra et al. (2026) further noted that students' problem-solving skills were enhanced by GeoGebra-assisted problem-based learning, while Saliao and Cajandig (2025) indicated that technology-enhanced instruction helps learners with effective visualization of concepts, test examples, and interpretation of results. Although limited studies focus specifically on hypothesis testing, the findings of this study indicate that GeoGebra's interactive features support students in visualizing sampling distributions, formulating hypotheses, and understanding test statistics, leading to deeper conceptual understanding and greater engagement beyond procedural learning.

From the results of the study, it could be inferred that both the combined Traditional method and GeoGebra-supported TEI and the traditional teaching method contributed to the improvement of students' performance in hypothesis testing; however, they did not achieve the same level of effectiveness. While both groups showed progress, the GeoGebra group demonstrated a statistically significant advantage over the Traditional group. Students in the GeoGebra group not only improved but also obtained higher posttest scores and greater mean gains, indicating a better understanding of both the conceptual and procedural aspects of hypothesis testing. Moreover, the presence of a moderate effect size suggests that integrating GeoGebra into traditional instruction has a meaningful impact on students' comprehension and application of statistical concepts. Overall, the findings indicate that combining GeoGebra with traditional teaching results in a more effective learning approach compared to using the traditional method alone.

In light of these findings, it is recommended that educators integrate GeoGebra into their instructional practices to create more interactive and concept-focused learning experiences in statistics. This approach is especially helpful in addressing diverse learning needs, as it promotes visualization and active engagement with abstract ideas. To support effective implementation, school administrators should provide ongoing professional development and training to equip teachers with the skills needed to use GeoGebra effectively. Additionally, instructional materials should be designed to fully utilize the software's interactive features, such as simulations and graphical tools, to enhance students' understanding. Future research is also encouraged to explore the application of GeoGebra in other areas of statistics, across different grade levels, and over longer instructional periods to further assess its potential in improving mathematics education.

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