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THE ROLE OF TEACHING TOOLS IN GEOMETRY: A COMPARATIVE ANALYSIS OF GEOGEBRA AND CONVENTIONAL METHODS ON STUDENTS' INDUCTIVE REASONING AND RETENTION

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Abstract

This study compared GeoGebra and traditional manual tools in guided discovery activities on the retention of Geometry students at Mindanao State University at Naawan-Integrated Developmental School. Using an experimental design, 120 Grade 9 students participated, divided equally between a GeoGebra and a manual tools group. A retention test showed no significant difference in scores between the groups. While a perception survey indicated GeoGebra's effectiveness, it did not outperform traditional tools. Spearman's rho revealed stronger correlations between reasoning and retention in the manual group, suggesting traditional tools may better link these skills. Future research could explore this phenomenon further.

Keywords: GeoGebra, Inductive Reasoning, Retention, Students' Perception.

I. INTRODUCTION

A. Rationale

The integration of technology in education has become a cornerstone of 21st-century learning, aimed at producing globally competitive graduates equipped with essential skills and competencies. In the Philippines, the K-12 curriculum seeks to elevate the quality of education, aligning it with international standards. In response, educators are increasingly turning to technological tools to enhance teaching and learning.

In Mathematics, various software applications have been developed to aid the visualization and exploration of complex concepts. One such tool is GeoGebra, a free interactive geometry and algebra software. While numerous studies have highlighted the positive impact of GeoGebra on students' performance, some research presents conflicting results [1, 2, 3, 4], warranting further investigation. This study seeks to address these inconsistencies by exploring GeoGebra's potential to improve students' inductive reasoning and retention abilities.

As educators continue to explore effective methods to enhance students' understanding, GeoGebra has attracted significant attention for its potential to strengthen inductive reasoning—a crucial cognitive skill in mathematics that enables students to draw general conclusions from specific cases, deepening their conceptual understanding. Studies by Reisa

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(2010) [5] , Zengin et al. (2012) [6], Tatar (2012) [7], and Birgin et al. (2021) [8] have demonstrated the benefits of GeoGebra in enhancing students' learning and retention. Based on this premise, it is hypothesized that by allowing students to actively engage in making conjectures through exploration, GeoGebra promotes stronger retention of knowledge.

Retention, the ability to retain and recall information over time, is fundamental to academic success. As Seifert (2009) [9] asserts, without retention, learning is incomplete; it must result in lasting changes in behavior or knowledge. While conventional teaching methods remain effective to some degree, incorporating dynamic tools like GeoGebra offers an opportunity to further enhance students' cognitive skills.

Several studies, including those by Roble (2016) [10], Gemechu (2017) [11], and Birgin et al. (2021) [8], have shown that dynamic geometry software not only improves critical thinking and mathematical performance but also increases students' engagement with the subject. Building on these findings, this study evaluates the effectiveness of GeoGebra in improving students' inductive reasoning and retention in Geometry.

B. Research Questions

This research explored the effectiveness of using GeoGebra as a teaching tool compared to the traditional manual drawing tools in the guided discovery activities on the topics on circles in Geometry. Specifically, the study answered the following questions:

1. What are the students' performances on the retention test?
2. Does the GeoGebra group perform better than the conventional group in the retention test?
3. What are the students' perceptions of GeoGebra's impact on their retention ability?
4. Is there a significant relationship between inductive reasoning performance and retention test performance in both groups?

By exploring these questions, this study aims to contribute to the growing body of literature on educational technology and provide insights into the potential benefits of incorporating GeoGebra into the mathematics curriculum. The findings could guide educators in enhancing students' mathematical reasoning, improving long-term retention, and fostering greater interest in the subject through innovative tools.

C. Research Hypothesis

The following null hypotheses were tested at 0.05 level of significance.

H_{o1}: There is no significant difference between retention test scores of the GeoGebra and Conventional group.

H_{o2}: There is no correlation between the inductive reasoning competency scores and the retention test scores of the GeoGebra group.

H_{o3}: There is no correlation between the inductive reasoning competency scores and the retention test scores of the Conventional group.

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II. MATERIALS AND METHODS

A. Research Design

This study utilized a two-group experimental design, involving four intact classes from which participants for both the experimental and control groups were randomly selected. The research was conducted throughout the third grading period of S.Y. 2022-2023. The GeoGebra group functioned as the experimental group, while the Conventional group served as the control. Only the experimental group had access to the computer laboratory, where they received instruction on the use of GeoGebra during the intervention period. In contrast, the control group was taught using traditional manual drawing tools, such as compasses, protractors, rulers, pencils, and paper.

The study took place at MSU N-IDS, with all four sections being taught exclusively by the researcher to eliminate any variability in teaching style that could affect the dependent variables. Descriptive and inferential evaluation techniques were employed, and data were gathered using teacher-designed inductive reasoning activity sheets, a retention test questionnaire, and a student perception survey.

B. Participants of the Study

The participants of this study were 120 Grade 9 students from Mindanao State University at Naawan – Integrated Developmental School, located in Naawan, Misamis Oriental, Philippines. This school was intentionally selected for practical reasons, including convenience, time, and cost-efficiency, as well as the researcher's ease of access to respondents, being a teacher at the institution. Grade 9 students were chosen specifically as they represent the group currently studying Geometry at MSUN-IDS, making them the most suitable sample for this study. Additionally, the school has yet to implement any formal directives regarding the integration of technology in Mathematics instruction, placing it behind in terms of technological, pedagogical, and content knowledge integration. It is hoped that the results of this study will act as a catalyst for positive change in this area.

C. Instrumentation

The study's instruments used to collect data were the Guided Discovery Activity Sheets, Retention test questionnaire and the Perception survey questionnaire.

1) ***Guided Discovery Activity Worksheets*:** The researcher developed seven exploratory activities, which were integrated into the Learning Module. These activities required students to construct and manipulate various geometric elements related to circles, including radii, chords, tangents, secants, inscribed angles, intercepted arcs, and perpendicular bisectors of chords. Students were guided to observe, explore properties and relationships among these elements, formulate conjectures, and test their hypotheses.

The activity worksheets, designed to assess students' inductive reasoning skills, were evaluated using a rubric. For the GeoGebra group, the worksheets were provided electronically, while the conventional group received printed versions.

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Additionally, two experts in secondary mathematics education reviewed the content and face validity of the activity worksheets and the usability of the Learning Module. Their evaluation was based on a rubric with clearly defined criteria.

2) ***Retention Test Questionnaire*:** The Retention Test Questionnaire comprised 25 multiple-choice items, three problem-solving questions, and three proof-based questions. To ensure reliability and validity, the questionnaire underwent the same validation process as the proficiency test. The retention test achieved a Cronbach's alpha of 0.82651, affirming its validity and reliability as a study instrument.

This questionnaire was administered two weeks after the study's conclusion, which spanned an entire grading period. Its purpose was to assess the students' retention of learning. Both the GeoGebra and conventional groups completed the questionnaire, allowing for a comparison of GeoGebra's impact on the experimental group's retention ability.

3) ***Perception Survey Questionnaire*:** The Students' Perception Survey Questionnaire included four Likert-scale statements and one open-ended question, all related to the software's impact on students' retention abilities. Each statement offered five response options, ranging from "Strongly disagree" to "Strongly agree." The purpose of this survey was to gauge students' opinions on how GeoGebra influenced their ability to retain information. The open-ended question aimed to gather more in-depth insights into the students' perceptions.

This survey was administered online via Google Forms and was answered exclusively by the GeoGebra group. Thematic analysis was used to cross-validate responses from the Likert-scale statements with the answers to the open-ended question. As with the other instruments, the survey underwent content and face validation.

The resulting Cronbach's alpha coefficient was .936233, significantly above the minimum threshold of 0.75, indicating the survey's reliability and appropriateness for future use.

III. RESULTS AND DISCUSSION

A. Students' Performance in the Retention Test

Table I: Mean, SD, And CV of the Retention Test Scores of the Geogebra and the Conventional Group

Group	N	Retention Test			Description
		Mean	SD	CV	
GeoGebra	60	18.33	6.1991	33.82%	Beginning
Conventional	60	18.18	6.1602	33.88%	Beginning

In the retention test, the mean score for both groups are relatively similar, with the GeoGebra group having a mean score of 18.33 and the Conventional group having a mean score of 18.18. Both groups demonstrate a proficiency level categorized as 'Beginning', which can be attributed to the students' limited foundational knowledge in problem solving and proving. This deficiency may be a result of the time vacuum created by the pandemic.

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The standard deviations for both groups are also similar, with the GeoGebra group having slightly higher SD value of 6.1991 compared to the Conventional group's SD of 6.1602.

The coefficient of variation (CV) for the GeoGebra group is 33.82%, indicating that there is a relatively higher degree of variability in the scores relative to the mean score. The CV for the Conventional group is slightly higher at 33.88%.

This means that the variability in the scores in both groups is relatively high relative to the mean score. The results suggest that the retention abilities of students who used the digital mathematics software, GeoGebra, and those who used manual drawing tools were somewhat similar.

Therefore, it can be inferred that both modes of instruction had a comparable effect on students' retention abilities.

B. Comparison between GeoGebra and Conventional Group's Performance in the Retention Test

Table II: Mann-Whitney U-Test Results for Retention Test Scores of the Geogebra and the Conventional Groups

Compared Groups	N	Mean	Sd	Mann-Whitney U	p-value	Interpretation at $\alpha = 0.05$
Experimental Group	60	18.33	6.1991			
(GeoGebra)				1766.5	0.86215	Not Significant
Control Group	60	18.18	6.1603			
(Conventional)						

A non-parametric Mann-Whitney U-test was used to compare the retention test scores between the GeoGebra and conventional groups. Table II presents the results, which show a p-value of 0.86215, greater than the significance level of 0.05. This indicates that we accept the null hypothesis $H_0 1$, which states that there is no significant difference between the scores of the two groups in the retention test.

It is worth noting that the GeoGebra group had a slightly higher mean score as compared to the Conventional group with a negligible difference of 0.15 points, with the former having a mean score of 18.33, while the latter having 18.18 points.

These results align with a study conducted by Vasquez in 2015[3], which also included a retention test and found no significant difference in overall achievement between the treatment and control groups.

This suggests that both GeoGebra and manual drawing tools have an equal effect on students' retention ability when used with the same teaching approach. This can be explained using Hattie's Ranking (2018) [12] of 256 influences and effect sizes related to students achievement, which says that technology in itself has a lesser impact to students' achievement when being used alone. Considering that both groups received equal teaching strategies, we can expect that the results are comparable.

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C. Students' Perception on GeoGebra's Effect on their Retention Ability

Table III: Students' Perception Rating on Geogebra's Impact on their Retention Ability

Statements	Number of Responses	Average Perception Rating	Interpretation
9. Discovered concepts through Explorations with the use of GeoGebra will most likely be remembered in the future.	60	4.1	High Positive
10. It provides opportunity to deepen my understanding of the concepts being investigated.	60	4.13	High Positive
11. It helps me remember the concepts I learned.	60	3.92	High Positive
12. I retain a lot more ideas and concepts with the use of GeoGebra.	60	3.98	High Positive
	Total Ave. rating:	4.03	High Positive

Table III provides the results of the four survey statements that asked students about their perception of GeoGebra's impact on their retention ability. The table includes four Likert-type statements, and the average ratings for each statement are provided, ranging from 1(Strongly Disagree) to 5 (Strongly Agree).

Statement 9 indicates that students believe that they are likely to remember concepts they discover through explorations with the use of GeoGebra in the future, and the average rating of 4.10 suggests that students hold a high positive perception of this statement.

Statement 10 suggests that GeoGebra provides students with an opportunity to deepen their understanding of the concepts they are investigating, and the average rating of 4.13 suggests that students also hold a high positive perception of this statement.

Statement 11 indicates that students believe that GeoGebra helps them remember the concepts they learned, and the average rating of 3.92 suggests that students still hold a high positive perception of this statement, although slightly lower than the previous two statements.

Lastly, statement 12 suggests that students retain more ideas and concepts with the use of GeoGebra, and the average rating of 3.98 suggests that students hold a high positive perception of this statement, similar to statement 11.

The overall average of these four statements is 4.03, which is interpreted as a high positive perception of GeoGebra's impact on students' retention ability. This suggests that students find GeoGebra to be a valuable tool in helping them learn and retain mathematical concepts.

Moving on to the thematic analysis of the open-ended question, *"How does GeoGebra help you remember the concepts you learned?"* The analysis revealed several themes, including visualization, engagement, practice and repetition, accuracy and ease of use, and social learning.

The most common theme was visualization, with many respondents commenting that GeoGebra's visual representations help them remember the concepts better. Below are some actual responses from the students.

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Student AGM4: ***"GeoGebra helps me Visualize mathematical concepts that can seem theoretical at times."***

Student BGM6: ***"It makes it easier and faster for me to remember, since it is clearer and more understandable."***

Student DGF2**:** ***"Students can visualize abstract mathematical ideas with the aid of GeoGebra."***

Student CGF6**:** ***"In multiple different ways, Geogbra's visual representation of mathematical ideas makes it easier for me to learn and to remember the concepts. I can form a mental picture of how the concepts function by seeing them in action, which can make it easier for me to recall them later. Additionally, an engaging, supportive learning environment can improve my comprehension and retention of mathematical subjects."***

Student AGF5***: "GeoGebra help me remember the concepts that I learned through visualization and it's easy to understand."***

The second most common theme was engagement, with several students mentioning that using GeoGebra is fun and engaging, which helps them to remember the concepts they learn. They appreciate that the program provides an interactive and interesting learning experience, rather than relying on traditional manual drawing tools.

The following are some of the actual responses:

Student AGM3***: "GeoGebra helps me remember the concepts I have learned because it is fun to use. People tend to remember things they did that were fun rather than boring things like drawing a circle over and over again because the paper keeps moving or classmates interrupting your work. Aside from that, the works created through GeoGebra can be saved easily, meaning that if you were to forget something, you can just look it up directly and relearn things."***

Student BGM3: ***"The use of GeoGebra can help me to remember the concepts I've learned by providing a more engaging and interactive learning experience that reinforces my understanding of the material."***

Student BGM1: ***"by doing the activities and its kinda fun using GeoGebra so it makes you remember more what you did."***

Student DGF7: ***"Using GeoGebra is fun so in that case, I won't be having a hard time remembering what I learned."***

Other themes include the following:

Accuracy and ease of use: Many respondents noted that GeoGebra is an accurate and reliable tool that makes it easy to measure and manipulate objects. The program's controls and labels help users to understand what each function does, and its accuracy ensures that the measurements are always exact. The following are some actual responses:

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Student AGF4*: "GeoGebra helps in my retention of the ideas I've learnt because, in addition to being simple to use, it also provides accurate measurements and angles for circles that are simple to understand. I can also learn a lot through GeoGebra."*

Student DGF3: *"Using geobra helps me remembering the concepts i have learned because geogebra is much easier to use than conventional or using manual drawing tools, so i can remember what i have learned while using geogebra."*

Student BGF6: "*Creating circles, segments, tangents, and many more. It is easy to draw a circle because you only click and drag, it is easier than manual."*

Student CGM3: *"It help me because of the labels and it's easy to know the measure of the angles and arcs to make generalizations."*

Social learning: A few respondents mentioned that GeoGebra enables them to participate in online work-sharing and social learning. By sharing their work online, they can actively and socially construct an understanding of Geometry and review each other's work. Some actual responses are presented below.

Student CGF11: *"Its aids in the social construction of my awareness of geometry by enabling active participation through work online share."*

Student AGM1: *"Geogebra help me socially construct an understanding of geometry."*

Student DGM3: *"It allows us students to actively and through the sharing of the work online, socially construct an understanding of geometry."*

Student DGF5: *"It allows me to actively and socially develop an understanding of geometry by sharing our work online, it also helps me to visualize mathematical topics and analyze it."*

Easy storage and accessibility: Some students highlighted the software's easy accessibility features, allowing them to effortlessly retrieve and review past lessons and files they have stored, thereby facilitating their retention process. The following are some of the actual responses:

Student DGF8: *"Dali ra siya tun an kay ma save man ang mga gi himo nimo sa GeoGebra pwede ra nimo e open dayun tun an."* (It's easy to study past lessons because you can save your work done with GeoGebra, so you can easily open your saved file for you to study.")

Student DGF10: *"I can easily look back to the pdf or to the file."*

Student DGF4: *"It is more advantage because it will store our information of past class in our phone without worry that we will lost our paper modules."*

In general, these responses suggest that GeoGebra is an effective tool for helping students to remember mathematical concepts by providing an engaging, interactive, and accurate learning experience that reinforces their understanding of the material.

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D. Relationship between Inductive Reasoning Competency and Retention Test Scores of the GeoGebra Group

Table IV: Spearman's Rho Correlation Test Results Between Inductive Reasoning Competency And Retention Test Scores Of The Geogebra Group

Variables	Mean	SD	Spearman's rho (r-value)	p-value	Interpretation at α = 0.05
Inductive Reasoning	23.37	5.1347	0.28212	0.02897	Significant
Retention Test	18.33	6.1991			

The Spearman's rho correlation test results between inductive reasoning competency and retention test scores for the experimental group using GeoGebra yielded an r-value of 0.28212, with a corresponding p-value of 0.02897, as shown in Table IV above. The r-value of 0.28212 suggests a **weak positive correlation** between inductive reasoning competency and retention test scores. This indicates that as students' inductive reasoning abilities improve, their retention scores tend to increase, though the relationship is not strong.

The p-value of 0.02897 is less than the commonly used significance level of 0.05. This suggests that the correlation observed is statistically significant. In other words, the likelihood of observing this correlation by chance is low, meaning there is a meaningful association between inductive reasoning and retention within the GeoGebra group.

E. Relationship between Inductive Reasoning Competency and Retention Test Scoresof the Conventional Group

Table V: Spearman's Rho Correlation Test Results Between Inductive Reasoning Competency And Retention Test Scores Of The Conventional Group

Variables	Mean	SD	Spearman's rho (r-value)	p-value	Interpretation at α = 0.05
Inductive Reasoning	22.17	5.1806	0.44858	0.000366	Significant
Retention Test	18.18	6.1603			

Table V shows the Spearman's rho correlation test results between inductive reasoning competency and retention test scores for the control group (using traditional manual drawing tools). The test yielded an r-value of 0.44858, indicates a moderate positive correlation between inductive reasoning and retention test scores. This suggests that students with higher inductive reasoning competency tend to achieve higher retention test scores. The relationship is more pronounced in this control group compared to the experimental group using GeoGebra, where the correlation was weaker.

The corresponding p-value of 0.000366 is well below the conventional threshold of 0.05, indicating that the correlation is statistically significant. This means there is a very low probability that this correlation occurred by chance, signifying a meaningful association between inductive reasoning and retention in the control group.

These findings can be supported by theories such as the Embodied Cognition Theory which suggests that learning and memory are deeply rooted in bodily interactions with the physical

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environment. The study conducted by Johnson-Glenberg et al. (2016) [13] found that incorporating more sensorimotor feedback and gestural congruency in educational technology can enhance learning retention. In this study, using manual tools may involve sensory and motor processes that reinforce cognitive understanding. Drawing with physical tools engages touch-related feedback, fine motor skills, and spatial reasoning, all of which create a multi-sensory learning experience that helps solidify the material in memory.

Another relevant theory is Paivio's Dual Coding Theory which posits that information is processed in two distinct channels: one for verbal information and one for visual information. Paivio's (1990) [14] work on dual coding theory highlights how students who create their own visual representations such as diagrams or drawings, during problem-solving tend to have better retention compared to those who don't. In this study, by manually drawing geometric shapes, students are likely engaging their visual-spatial reasoning along with motor skills. When this is coupled with verbal reasoning, it reinforces memory traces in both the visual and verbal systems, leading to deeper encoding and better recall.

While both the control and experimental groups show a statistically significant correlation between inductive reasoning and retention, the stronger correlation in the control group might imply that traditional tools foster a more direct link between reasoning skills and retention. This does not necessarily diminish the potential benefits of GeoGebra but rather highlights different impacts on learning processes in each method. Further analysis could explore why the use of traditional tools strengthens this relationship more than GeoGebra does.

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