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The Effectiveness of Diagnostic Assessments and GeoGebra-Assisted Learning on Learning Outcomes Reviewed from Learning Styles

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Abstract

This study aims to analyze the effectiveness of providing cognitive and non-cognitive diagnostic (learning style) assessments and recognizing students' learning styles before the learning process occurs. The results of this study show that, typically, the diagnostic assessment process is not implemented before learning activities begin, and that the learning process proceeds without first taking into account the learning style of the students. This study also analyzes the effectiveness of the use of GeoGebra in learning as a solution to facilitating various student learning styles. The research was carried out in 2 schools, namely SMA Negeri 2 Kefamenanu and SMA Katolik Warta Bakti Kefamenanu, utilizing a Pre-Experimental design, with a total of 53 students chosen by a purposive sampling technique. Data were collected using questionnaires and test questions, then analyzed using the Kruskal-Wallis and Wilcoxon Signed Test methods to compare the student groups from each school. The results indicate that the average mathematical diagnostic assessment score was 16.4553. After utilizing GeoGebra during learning and focusing on student learning styles, the students' average mathematical ability score increased to 62. This result is supported by the Kruskal-Wallis Test and Wilcoxon Signed Test, indicating that the average of the mathematical ability score from the diagnostic assessment reaches near-equilibrium after the students are exposed to GeoGebra. The increase in students' ability by 55% on the N-Gain Test shows that learning by utilizing GeoGebra is quite effective in improving students' mathematical skills. These results lead to the conclusion that learning by using GeoGebra during learning after cognitive diagnostic assessments and paying attention to students' learning styles is the best way to improve student learning outcomes.

Keywords: diagnostic assessments; GeoGebra, Kruskal-Wallis test; pre-experimental; Wilcoxon signed test.

INTRODUCTION

Mathematical skills have become crucial competencies in the 21st century, where individuals are required to understand, interpret, and apply mathematical concepts in various life contexts. However, mathematical skills in Indonesian students remain below expectations compared to those in different countries (Setiawan et al., 2022). The results of the latest international assessments show a troubling trend. The 2022 Program for International Student Assessment (PISA) data places Indonesia in 66th place (out of 81 countries surveyed) with an average math score of 366, which is well below the Organization for Economic Co-operation and Development (OECD) average math score of 472 (OCDE, 2024). Similar findings were reported in the Trends in International Mathematics and Science Study (TIMSS) in 2019, where only 9% of Indonesian students achieved at a high level in mathematics (Mullis et al., 2019). The low achievement in mathematical ability indicates that there is a fundamental problem in mathematics learning in Indonesia. Several studies identified causative factors, including: (1) assessment practices that are not optimal (Badan Standar Asesmen Pendidikan, 2021; Heritage, 2010; Rokhim et al., 2021); (2) conventional learning approaches (Andrian & Effendi, 2023; Mullis et al., 2019; Price & Carstens, 2012); (3) student learning aids are still minimal (Othman, 2025), and; (4) lack of connection of the material with the real-world context (Putri & Zulkardi, 2020).

Research of Mangelep et al. (2023) shows that students with a good understanding of concepts and problem-solving skills will also possess strong mathematical skills. This will, of course, improve learning outcomes. These learning outcomes are used as a form of assessment process, and this assessment process provides many benefits in the educational process (Holmes, 2019). In this assessment context, cognitive and non-cognitive diagnostic assessments are essential to discover the learner's initial understanding, learning barriers, and also personal characteristics such as learning styles (visual, auditory, or kinesthetic). Diagnostic assessments that are designed to identify students' specific learning difficulties are often overlooked in daily learning practices (Black & Wiliam, 2018). Diagnostic assessments should play a role in identifying gaps in student understanding before learning begins, allowing teachers to design targeted interventions. Meanwhile, non-diagnostic assessments (such as observations, anecdotal notes, or self-reflection) that are supposed to monitor learning progress without providing assessment pressure, while encouraging active student engagement, tend to focus on measuring outcomes rather than providing feedback for improvement of the learning process. This leads to stunted student learning development, meanwhile, the combination of these two types of assessments (diagnostic and non-diagnostic) can provide comprehensive information about students, provide ongoing feedback, and help teachers tailor learning approaches according to individual student needs.

The results of observations at SMA Negeri 2 Kefamenanu and SMA Warta Bakti Kefamenanu Catholic Private High School show that these two schools have not mapped student learning outcomes, which include cognitive, affective and psychomotor abilities. Learning outcomes focused on cognitive abilities however, mathematics teachers have also not identified the level of student difficulty and understanding in learning mathematics. This is likely to happen because the diagnostic assessment process does not occur before learning begins. Neither cognitive diagnostic assessments nor non-cognitive diagnostic assessments are implemented before the learning process. This results in learning occurring without adjusting teaching based on students' initial abilities and without considering non-cognitive issues such as learning styles. Research of Hassan et al. (2024) shows that formative assessments that are conducted to provide feedback to students, monitor, identify, and correct errors during the learning process improve student learning outcomes compared to summative assessments that focus on assessment at the end of a specific academic period. This shows the importance of conducting an assessment at the beginning of the meeting and using the results of the assessment as a basis to provide learning that adjusts to students' abilities so that they can continue to be used as improvements in the learning process.

One of the breakthroughs in learning mathematics is the use of digital tools such as GeoGebra, which facilitates the visualization of abstract concepts to connect to real-world concepts. Geogebra can not only be used in learning algebra. Mathematical operations, such as the subject of ranked numbers, can also be learned by utilizing this application (Tuda & Rexhepi, 2023). This is especially needed for students with kinesthetic learning styles who need practice in learning. With GeoGebra, problems such as finding patterns and defining numerical relationships become easier. GeoGebra integrates geometry, algebra, statistics, mathematical operations, and calculus in one interactive platform, so that it can support students in understanding the material more effectively (Dahal et al., 2022). However, the effectiveness of this digital tool needs to be analyzed further, especially in relation to student learning styles/patterns, because each student has a different method of receiving information (Vacalares et al., 2024). Integration of GeoGebra in the learning process is expected to improve mathematics learning outcomes, but its effectiveness may vary depending on the fit for the student's learning style (Ishartono et al., 2022; Sumarauw et al., 2024). For example, students who have a visual learning style may be more helped by GeoGebra graphics and animations, while those students with a kinesthetic learning style may need increased interaction, such as practicing using GeoGebra (Farihah, 2018; Sieng, 2024; Uwurukundo et al., 2022). On the other hand, auditory students may need a verbal explanation that accompanies the use of such digital tools.

Many studies have utilized GeoGebra in learning and even linked it to learning styles. However, not many researchers conduct cognitive and non-cognitive assessments at the same time before carrying out learning. Therefore, this study aims to analyze the effectiveness of cognitive and non-cognitive diagnostic assessments and to recognize students' learning styles before the learning process, and to determine the impact of GeoGebra on students' mathematics learning outcomes. In addition, this study aims to assess whether the use of GeoGebra provides a significant improvement in learning outcomes based on the results of diagnostic assessments and understanding of student learning styles. Therefore, this study is expected to provide suggestions for more effective strategies to enhance learning, especially in the use of technology such as GeoGebra, by understanding the variation of students' learning styles and students' initial cognitive abilities to achieve maximum learning outcomes.

METHOD

This study utilizes a quantitative research method with a pre-experimental design (single student group given pretest and posttest assessments) (Oktawirawan, 2020). Therefore, before being given treatment (GeoGebra), cognitive diagnostic assessments and non-cognitive diagnostic assessments (learning styles) are first administered to analyze students' initial understanding. Furthermore, the results of this diagnostic assessment will be used as constructive input to optimize the learning process. Supplementing the learning process by utilizing GeoGebra teaching aids is done to overcome the gap in learning outcomes for each learning style. Using GeoGebra in the learning process is expected to provide more homogeneous results in the three learning styles (Visual, Auditory, and Kinesthetic) while still focusing on the results of the (cognitive and non-cognitive) diagnostic assessments. The treatment (using GeoGebra) will end with a Posttest. In general, the flow chart for this research can be seen in Figure 1.

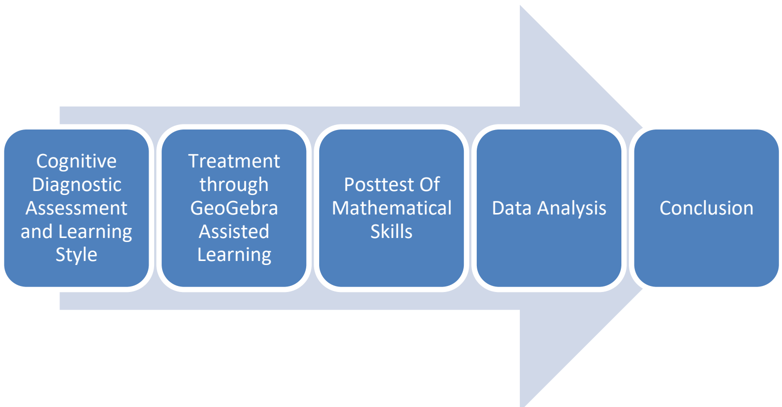

Figure 1. Research Flow Diagram

The research flow diagram in Figure 1 explains that the research process begins with conducting cognitive diagnostic assessments and non-cognitive diagnostic assessments in the form of student learning style assessments. The results of cognitive diagnostic assessments based on learning styles gave the smallest results in kinesthetic learning styles. This is the basis for providing treatment for students with Geogebra-assisted learning. The treatment ended by giving a final test to measure the students' mathematical ability after being given the treatment. The data obtained was then analyzed with appropriate methods, and conclusions were obtained that answered the purpose of this study.

This research was carried out at SMA Negeri 2 Kefamenanu and SMA Swasta Katolik Warta Bakti Kefamenanu in the ‘Odd’ semester (Semester 1: September through February) of the 2024/2025 Academic Year. One (1) class in each school was used as an experimental class (where the treatment used was learning with GeoGebra teaching aids). These two schools were selected as samples, both have the same quality and have implemented the Merdeka curriculum in learning. In addition, students at these two schools have the same initial abilities. These two schools are quite representative of schools in North Central Timor Regency, namely public schools and private schools. Overall, the sample used was 53 people, 28 people from SMA Negeri 2 Kefamenanu, and 25 others from SMA Swasta Katolik Warta Bakti Kefamenanu. Samples were selected in each school as many as 1 class, with the Purposive Sampling technique the considering that class XI is a class that is implementing the curriculum. In addition, the number of samples that do not differ significantly is expected not to affect the analysis and to avoid bias due to the subjectivity of sample selection. Therefore, all students in the selected class as a sample were used in the analysis process. The full research design can be seen in Table 1

Table 1. Research Design

Cognitive Diagnostic Assessment (A)	Learning Styles (B)	GeoGebra Assisted Learning (C)
High (A_1)	Visual (B_1)	A_1B_1C
Low (A_2)		A_2B_1C
High (A_1)	Auditory (B_2)	A_1B_2C
Low (A_2)		A_2B_2C
High (A_1)	Kinesthetic (B_3)	A_1B_3C
Low (A_2)		A_2B_3C

Information:
A_1B_1C: The results of mathematical ability in GeoGebra-based learning classes show that students with high abilities with visual learning styles. The stages, processes, outputs, and achievement indicators at each stage can be seen more clearly in Table 2.

Table 2. Stages, Processes, Outputs, and Achievement Indicators

Stages	Processes	Outputs	Achievement Indicators
Preparation	Development of diagnostic assessment instruments (cognitive & non-cognitive Learning Style).	Assessment instruments (Istiqlal et al., 2024), (Hartoyo et al., 2024)	Validated and reliable assessment instruments (Cronbach's Alpha > 0.7). (The researcher uses a valid instrument)

Stages	Processes	Outputs	Achievement Indicators
Implementation	GeoGebra Assisted Learning	Learning plan for the use of GeoGebra and Teaching Modules	The lesson plan for the use of GeoGebra and Teaching Modules has been used
Evaluation	Test the beginning ability differences based on learning styles	Kruskal-Wallis test results (Quraisy & Hasni, 2021)	Significant improvement (p-value < 0.05), which means that there is a difference in the beginning ability of students with different learning styles
	Test of differences in final abilities after the implementation of GeoGebra-assisted learning	Kruskal-Wallis test results (Quraisy & Hasni, 2021)	(p-value > 0.05) which means that there is no difference in the final ability of students with different learning styles
	Test the difference in beginning and final abilities to see the extent to which GeoGebra-assisted learning can be used as a learning reference for different learning styles.	Wilcoxon test results for paired samples (Triwiyanti et al., 2019)	(p-value < 0.05) which means that there is a significant difference between the student's initial ability and the student's academic ability. This difference refers to the initial ability being no greater than the final ability.
	Student Mathematical Ability Improvement Test (N-Gain Test)	N-Gain test result (Sukarelawan et al., 2024)	Percentage Increase according to the N-Gain Indicator

Hypothesis testing is described in detail as follows.

1. **Normality Test:**
   To ensure that the data tested is normally distributed so that it can be used for parametric statistical analysis. (Widhiarso, 2000), then the researcher uses the Kolmogorov-Smirnov Test:
   H_0 : Data is normally distributed
   H_1 : Data is not normally distributed
   This test will give a rejection conclusion to, H_0 if the resulting Sig. value < 0.05.

2. **Kruskal-Wallis Test:**
   To solve non-normal data or non-fulfillment of parametric statistical usage requirements, the ANOVA test was replaced with the Kruskal-Wallis test to see a difference of more than two groups on average.
   H_0 : There is no difference in the average results of students' diagnostic assessments reviewed from learning styles

H_1 : There is a difference in the average results of students' diagnostic assessments reviewed from learning styles

H_0 : There is no difference in the average results of students' diagnostic assessments reviewed by ability level

H_2 : There is a difference in the average results of students' diagnostic assessments reviewed by ability level

H_0 : There is no difference in the average results of students' posttest results reviewed from learning styles

H_3 : There is a difference in the average results of students' posttest results reviewed from learning styles

This test will give a rejection conclusion to, H_0 if the resulting Sig. value < 0.05.

3. **Wilcoxon Signed Ranks Test for Paired Samples:**
   This test was used to see if there was a difference in mathematical skills before and after being given learning using GeoGebra. The hypotheses tested are:
   H_0 : There is no difference before and after GeoGebra-Assisted learning
   H_1 : There is a difference before and after GeoGebra-Assisted learning

4. **Mathematical Ability Improvement Test (N-Gain Test):**
   The N-Gain test is carried out in order to test how much the students' mathematics ability has improved. The formula used refers to Hake (1999), namely:

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Ideal\ Score - Pretest\ Score} \ldots (1)$$

The results of the N-Gain test can be classified based on the following criteria:

Table 3. N-Gain Criteria

N-Gain	Interpretation
$0.70 \leq g \leq 1.00$	Effective
$0.30 \leq g < 0.70$	Quite Effective
$0.00 < g < 0.30$	Ineffective

RESULTS

Hypothesis testing began by looking at descriptive statistics from the overall data from the 2 schools where the research was implemented. The data are shown in Figure 2 and Table 3 below.

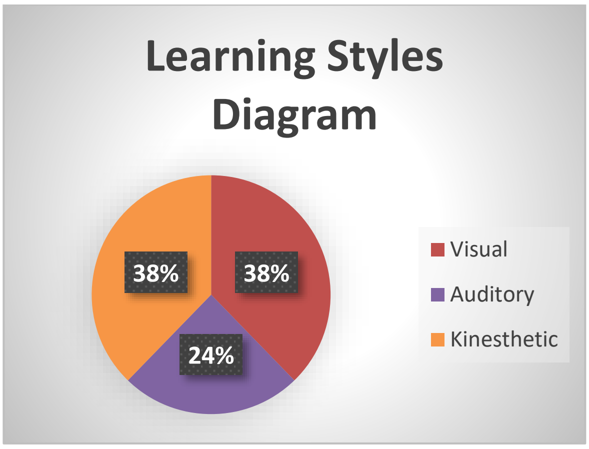

Figure 2. Learning Styles Diagram

From Figure 2, the distribution of learning styles from 53 students can be seen, where 20 students (38%) each have Visual and Kinesthetic learning styles, while the other 13 students (24%) have Auditory learning styles. These results show that students' learning styles are quite diverse, so the learning context needs to be adjusted to accommodate the balance of each learning style. The results of the diagnostic assessment (Cognitive Ability and Learning Style) obtained then became the basis for the implementation of learning. Table 4 explains the results of descriptive statistical mathematical skills before and after being given learning that makes the assessment results the basis for it.

Table 4. Descriptive Statistical Results

	N	Mean	Std. Deviation	Minimum	Maximum
Diagnostic Assessment	53	16.4553	15.15727	.00	76.92
Posttest	53	62.6415	24.50675	20.00	100.00

Descriptive statistics in Table 4 show that, on average, students' mathematical ability increases. The average mathematical ability, which was initially 16.4553, increased to 62.6415. The value of 16.4553 is spread based on learning style, namely visual learning style with an average score of 24.45, auditory learning style with an average score of 17.43, and average cognitive ability of kinesthetic learning style, which is 8.99. It can be seen that kinesthetic learning styles need to be used as the main focus of improving students' mathematical skills. Although descriptively it can be seen that there is an increase in mathematical ability before and after treatment, to prove it, it is necessary to test hypotheses.

Normality Test

Before proceeding to hypothesis testing, the data is first tested for normality to determine whether the data is distributed normally, for further testing purposes. The hypotheses tested are as follows:

H_0 : Data is normally distributed

H_1 : Data is not normally distributed

Table 5. Table of Normality Test Results

			Diagnostic Assessment	Learning Style	Post-test
N			53	53	53
Normal Parameters[a,b]	Mean		16.4553	2.0000	62.6415
	Std. Deviation		15.15727	.87706	24.50675
Most Extreme Differences	Absolute		.141	.250	.195
	Positive		.141	.250	.143
	Negative		-.139	-.250	-.195
Test Statistic			.141	.250	.195
Asymp. Sig. (2-tailed)[c]			.010	.000	.000
Monte Carlo Sig. (2-tailed)[d]	Sig.		.011	.000	.000
	99% Confidence Interval	Lower Bound	.008	.000	.000
		Upper Bound	.014	.000	.000

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. Lilliefors' method based on 10,000 Monte Carlo samples with starting seed 2,000,000.

The results of the normality test in Table 5 indicate that the data are not normally distributed because Asymp. Sig. (2-tailed) produced are 0.000 <0.05, so the hypothesis testing is switched to using the nonparametric method.

Kruskal-Wallis Test:

Test Differences in Students' Initial Abilities Based on Learning Styles

The test begins by testing whether there is a difference in the initial ability of students with different learning styles. The hypotheses tested are:

H_0: There is no difference in the average results of students' diagnostic assessments reviewed from learning styles.

H_1 : There is a difference in the average results of students' diagnostic assessments reviewed from learning styles

Hypothesis testing with the Kruskal-Wallis method gives the results as shown in Table 6.

Table 6. Results of Kruskal-Wallis Test (for Learning Styles)

	Diagnostic Assessment
Kruskal-Wallis H	7.951
Df	2
Asymp. Sig.	.019

a. Kruskal-Wallis Test

b. Grouping Variable: Learning Styles

Kruskal-Wallis test results in Table 6 give the result that is based on Asymp. Sig. > 0.05, it can be concluded that there is a difference in students' initial abilities based on learning styles. The lowest initial ability of students is in the kinesthetic learning style.

Test the initial ability difference based on the ability level indicator

In addition to looking at initial abilities based on learning styles, the researcher also analyzed the differences in students' initial abilities based on 2 ability indicators that have been determined, namely High and Low. The hypotheses used are:

H_0 : There is no difference in the average results of students' diagnostic assessments reviewed by ability level

H_2 : There is a difference in the average results of students' diagnostic assessments reviewed from learning styles

Hypothesis testing with the Kruskal-Wallis method gives the results in Table 7 as follows.

Table 7. Table of Results of the Kruskal-Wallis Test (for Assessment Category)

	Diagnostic Assessment
Kruskal-Wallis H	5.757
Df	1
Asymp. Sig.	.016

a. Kruskal-Wallis Test

b. Grouping Variable: Assessment Category

The results of this test show that as many as 96.23% (51 from 53) of students are still in the low category with scores less than 50. This is certainly very concerning, considering that diagnostic assessment questions are questions that only measure the level of students' initial ability. The results of the statistical test gave Asymp results. Sig. is 0.016, which is more than 0.05. This will confirm the conclusion that there is a difference in the average results of students' diagnostic assessments reviewed from learning styles. This conclusion is also supported by the descriptive statistics listed in Table 4 that there is a significant difference in the results of diagnostic assessments. The difference is clearly seen from the results of very small diagnostic assessments in students with kinesthetic learning styles.

Test Differences in Final Ability After Using GeoGebra-Assisted Learning

Hypothesis testing was then continued to see if students' mathematical abilities were still different after the application of GeoGebra-based learning. The hypotheses used are:

H_0 : There is no difference in the average results of students' posttest results reviewed from learning styles

H_1 : There is a difference in the average results of students' posttest results reviewed from learning styles

The results of the hypothesis test can be seen in Tables 8 and 9 below.

Table 8. Results of the Kruskal-Wallis Test (Descriptive Statistics)

	N	Mean	Std. Deviation	Minimum	Maximum
Diagnostic Assessment	53	16.4553	15.15727	.00	76.92
Posttest	53	62.6415	24.50675	20.00	100.00

Table 8 shows that before being given learning by utilizing the results of the diagnostic assessment, the average score obtained by students was 16.4553. As explained earlier, these results show that students' abilities are at a very basic level. After learning by utilizing the results of the diagnostic assessment, an average score of 62.6415 was obtained. Statistically, these results indicate that students' mathematical abilities are better. Table 8 also provides Posttest results that are differentiated based on learning style. It can be seen that the resulting values do not differ significantly. The above hypothesis will be proven more clearly based on the results of the Kruskal-Wallis test in Table 9.

Table 9. Results of the Kruskal-Wallis Test (Test Result)

	Posttest
Kruskal-Wallis H	3.834
Df	2
Asymp. Sig.	.147

a. Kruskal-Wallis Test
b. Grouping Variable: Learning Styles

In addition to being described in Table 8 that there is no significant difference, Table 9 also gives the same results based on the Mean Rank value produced. The results of the statistical test also gave Asymp results. Sig. of 0.147, which is more than 0.05. This hypothesis test indicated that there was no difference in learning outcomes in the Posttest. Descriptively, it can be seen that the mean Rank looks almost the same for all three learning styles. This demonstrates that by focusing on the three different learning styles, the results obtained by students are closely aligned. Statistically, it was also found that learning with the help of GeoGebra and focusing on students' differing learning styles tended to give better results.

Wilcoxon Signed Ranks Test for Paired Samples

Test the Difference in Mathematical Ability Between Diagnostic Assessment and Posttest

The test was continued by testing the difference between the results obtained in the diagnostic assessment and the results after the application of GeoGebra-assisted learning. The hypotheses tested are:

H_0 : There is no difference before and after GeoGebra-Assisted learning

H_1 : There is a difference before and after GeoGebra-Assisted learning

The results of the hypothesis test can be seen in detail in Table 10.

Table 10. Wilcoxon-Signed Test Result

	Posttest - Diagnostic Assessment
Z	-6.328[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

The results of the statistical test in Table 10 showed that only one student was in a negative rank (a posttest score obtained less than the results of a diagnostic assessment), while the other 52 students were in a positive rank (a posttest score obtained more than the results of a diagnostic assessment). This led to further statistical test results that gave Asymp results. Sig. (2-tailed) i.e., 0.000, which is smaller than 0.05. The results of the hypothesis test show that H_0 was rejected, or in other words, we can conclude that there are differences in learning outcomes before and after using GeoGebra teaching aids to supplement the learning process. This is supported by the fact that the average score at the time of the diagnostic assessment of 16.4553 was increased to 62.6415.

Mathematical Ability Improvement Test (N-Gain)

Because in the previous test, it was found that the students' mathematical ability increased from 16.4553 to 62.6415, so the N-Gain Test was applied to see the percentage increase in mathematical ability after students were given GeoGebra-based learning aids. The N-Gain test gave the following results.

Table 11. Table of N-Gain Test Results

Statistics N_Gain_Persen		
N	Valid	53
	Missing	0
Mean		55.1599
Std. Error of Mean		4.07312
Median		54.2857
Mode		100.00
Std. Deviation		29.65275
Variance		879.286
Skewness		-.119
Std. Error of Skewness		.327
Kurtosis		-.981
Std. Error of Kurtosis		.644
Range		104.00
Minimum		-4.00
Maximum		100.00
Sum		2923.47
Percentiles	25	31.7987
	50	54.2857
	75	79.1992

The percentage improvement in students' mathematical ability is 55.16% (see Table 3). Therefore, it can be concluded that improving students' mathematical abilities through GeoGebra-based learning by paying attention to learning styles is in the ‘Quite Effective’ category.

DISCUSSION

This study utilizes a quantitative research method with a Pre-Experimental design, which, of course, has weaknesses, including not comparing the research class with the control class. This was done by the researcher because the main purpose of this study was to see the extent of changes in the sample group after being given treatment without comparing it with other groups. Therefore, to enlarge the research sample, the researcher chose two schools and analyzed them without comparing the two schools, but focused on the change in students' mathematical abilities after being given an assessment and continued with learning that focused on each student's learning style.

The statistics in Figure 2 show that the students' learning styles are very diverse. In Table 4, it is noted that the average results of diagnostic assessments are very low. From these low scores, kinesthetic learning styles occupy the lowest position (as seen in Table 4). This will certainly have a serious impact if teachers choose to ignore the impact of learning styles on learning effectiveness. Based on this circumstance, the researcher then conducted several hypothesis tests as follows.

Differences in Students' Initial Abilities Based on Learning Styles and Ability Level Indicators

In addition to the descriptive statistics that have been presented, the researchers also tested hypotheses to assess whether there are differences in initial abilities based on learning styles. The Kruskal-Wallis test indicates that there are differences in students' initial abilities, both based on learning style and on the level of students' ability. Research Septiani et al. (2024) shows that teachers need to implement teaching methods that accommodate all learning styles, even though the material provided is theoretical. By implementing teaching methods that emphasize a visual experience, practicum activities, and auditory-based discussions, it will accommodate all students' learning styles, so that learning becomes more inclusive and effective. In addition, there are references from the research by Purwanto et al. (2020) which states that students with visual learning styles prefer learning by utilizing visual media such as pictures and maps to learn about places rather than detailed explanations. Students with an auditory learning style are more interested in learning with good tones and intonation, such as playing learning videos that have sound effects, while students with a kinesthetic learning style prefer learning that makes them active, such as project-based learning, demonstration methods, and practicums.

In accordance with the previous explanation, of the three learning styles, the kinesthetic learning styles rank the lowest (See Table 4 – ***Diagnostic Assessment***), and almost all of the students are at a low level of ability. Therefore, the focus should be on the supporting kinesthetic learning styles, while still paying attention to the other two learning styles. To overcome this kinesthetic learning deficit, the researchers then implemented learning assisted by the GeoGebra digital tool. GeoGebra-assisted learning is expected to reach students with kinesthetic learning styles so that they can directly practice what they learn through teaching aids. This is supported by research by Munyaruhengeri et al. (2025) which states that the use of Gegebra in learning hones creativity, self-expression, critical thinking skills, and emotional development of students. In a study by Loc et al. (2022) Researchers who developed the learning process and utilized GeoGebra as one of the learning tools found that learning that used 3 phases that focused on motivation and goal-oriented, knowledge formation, and practice and consolidation had better mathematical skills. Therefore, the use of GeoGebra is also expected to improve students' mathematical abilities so that there is less of a gap between high and low ability students.

Differences in Students' Final Abilities Based on Learning Styles and Ability Level Indicators

GeoGebra-based learning provides significant results. Table 8 (***Ranks***) provides more uniform results for all three learning styles. If in the initial ability analysis, 96.23% (51/53) of students were in the low category, after utilizing GeoGebra-based learning, this percentage dropped to 32% (17/53). This is supported by hypothesis testing with the Kruskal-Wallis Test, which gives the result that there is no difference on average in the Posttest values. These results are supported by research, Farihah. (2018) which states that the use of GeoGebra has affected the ability to solve mathematical problems not only for visual students but also for non-visual students. Students also have different ways of solving math problems, by adapting to their respective learning styles. Research Septian (2022) and Wawan (2017) also shows that the use of GeoGebra in learning, with the same two methods or with different methods, gives better results.

Differences in Students' Initial and Final Abilities and Results of Improvement Test (N-Gain)

The fact that the average score at the time of the diagnostic assessment (16.4553) was increased to 62.6415 is sufficient proof that learning using GeoGebra can actually standardize students' mathematical abilities within a narrow range, especially with diverse learning styles. In addition, the results of the Wilcoxon Signed test also provide results that students' final abilities are not that different, even when viewed through the learning style lens. Besides the fact that the use of GeoGebra in previous research studies has shown significant results, each student also experienced an improvement in mathematical skills. This can be seen from the results of the N-Gain test, which provides an average increase of 55%. Research by Imam et al. (2025) shows that the increase in student learning outcomes occurs because students are motivated to learn. The use of GeoGebra, which is a technological approach, stimulates students' desire to learn and improve their abilities. Further, Sarkar & Howlader (2025), the use of technology, such as GeoGebra, makes students more interested in developing their exploration skills. Students can easily explore various features that exist, which makes it easier for students to understand difficult mathematical material and associated problems. However, to teach students using GeoGebra, teachers need to be equipped with a good understanding of mathematical content and a good understanding of GeoGebra so that the use of the technology and pedagogy can operate in an optimal manner to support students' conceptual understanding (Sarah & Batiibwe, 2024). Research of Amadeus & Yulianti (2025) also supports that the use of GeoGebra can improve computational skills, mathematical resilience, and solve more complex problems by utilizing technology.

CONCLUSION

As previously explained, the results of observations at SMA Negeri 2 Kefamenanu and SMA Warta Bakti Kefamenanu Catholic Private High School show that the diagnostic assessment process does not occur before learning begins. Neither cognitive diagnostic assessments nor non-cognitive diagnostic assessments are implemented before the learning process. This is a challenge for researchers to get used to teachers and students carrying out assessments at the beginning of learning. In addition, because Mathematics teachers have also not identified the level of student difficulty and understanding in learning mathematics, the learning preparation process becomes longer because teachers are guided to prepare learning based on the results of identifying students' ability levels. But based on the results of the research that has been presented, it can be seen that students tend to have different learning styles. This will certainly have implications for the differences in students' abilities. Descriptive statistics show that out of 53 students, the average results of the diagnostic assessment look heterogeneous. The average diagnostic assessment was 16.4553 (Visual=24.45, Auditory=17.43, and Kinesthetic=8.99). The researchers implemented GeoGebra digital tool-based learning to overcome this gap in mathematical ability and found significant results. Students' mathematical ability increased to 62.6415 (Visual=67.50, Auditory=52.31, and Kinesthetic=62.00). The results of the hypothesis testing led the researchers to the conclusion that GeoGebra-based learning aids can improve mathematical skills. The results of the N-Gain test also showed that this learning was quite effective, with an average percentage of student ability improvement of 55.15%. Therefore, this learning tool (GeoGebra) can be used as a solution for students' low initial abilities, especially with classes containing diverse learning styles. Researchers are then expected to conduct research by paying attention to the results of assessments in other categories, such as learning readiness and students' psychological conditions. By paying attention to the results of this assessment and combined with cognitive assessment, it is hoped that teachers can determine the best learning method to improve students' abilities. This research is very possible to continue by designing modules or teaching materials that are in accordance with the learning style or the results of the initial diagnostic assessment.

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