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The Role of GeoGebra in the Sustainable Learning of Logarithmic Functions

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Abstract

Nowadays with the advanced of technology, education systems are under increasing pressure to keep up with the times. As a result of rapid technological progress and change, those who are responsible for the development of educational curricula are forced to consider how new and innovative teaching and learning approaches can be applied. In this study, we will try to give some results on how to use the GeoGebra program in teaching practice to address topics for presenting and reviewing logarithmic functions. In this study, the mixed method was used as the main methodology with action research. The selected sample included 37 students, while the data collection instruments were tests and questionnaires. The results of the study show that the experimental group performed much better after the intervention with the action plan compared to the results of the pre-test and that of the control group. Implications for this study show using GeoGebra in the math teaching process helps students develop basic math skills. Well-organized and well-planned support with this program, as well as ample activities helps many students to solve various problems around the topics of logarithmic functions.

Keywords: *Logarithmic Functions, GeoGebra, Teaching, Learning*

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1. Introduction

Mathematical reasoning skills are at the core of understanding and interpreting the many concepts required for meaningful and consistent learning. Sustainable learning can be addressed at all levels of the math curriculum. Thus, there are many ways to introduce this approach to logarithmic functions which are an important part of the mathematics curriculum in high schools and are critical to being taught effectively. It is widely regarded as a difficult subject for both the instructor and the learner. A function is a "link between input and output values, the output value depends on the input, which has only one output for each input value" (Holliday, et al., 2008). Students must possess the ability to tackle problems involving functions, like those who are proficient in graphing basic exponential functions, $f(x) = b^x$ to construct the graph $f(x) = \log_b x$, using a tabular method. This illustrates the process of converting an exponential function into its corresponding logarithmic function, demonstrating their inverse relationship (Makgakga & Sepeng, 2013).

On the other hand, through technology, many phenomena that were previously abstract in the subject of mathematics are becoming concrete. Hence, educators should incorporate innovative technology in the classroom to foster a genuine appreciation for mathematics among their students. Technology is a tool that stimulates the learning process and therefore students are actively involved in the construction of their knowledge (Nzaramyimana, 2021). The teaching process in mathematics is changing rapidly in parallel with science revolutions and the evolution of technology.

Thus, the primary aim of these technological advancements is to lead and support students through a continuous and sustainable learning process. Through this, they visualize and analyze the solution of changing problems. Technology helps students understand math concepts and affects how math is taught effectively (Nzaramyimana, 2021). Specifically, the integration of GeoGebra in mathematics classes fosters an interactive learning atmosphere, enabling students to grasp concepts through visual representation. Visual images help to attract students' attention and engage them in the learning process. GeoGebra can also improve students' ability to visualize learned mathematical concepts, enabling them to interact with them either individually or in group work (Saha, Ayub, & Tarmizi, 2010).

GeoGebra is a versatile mathematical software suitable for various educational levels, encompassing arithmetic, geometry, algebra, and statistics. It serves as an integrated tool blending geometry and algebra, with a specific focus on enhancing mathematical comprehension among students (Mushipe, 2016). GeoGebra provides a powerful interactive learning platform where users can generate mathematical entities and engage with them in diverse ways. It allows users to construct models representing mathematical ideas and their interconnections. Additionally, GeoGebra facilitates hypothesis testing, enables the creation of lifelike simulations, and allows for the emulation of real-world scenarios, all while conducting statistical analyses and generating graphs. Moreover, this program generates numerous dynamic representations of mathematical objects (Phan-Yamada & Man, 2018).

The conventional method involving chalkboard instruction and rote memorization of procedures and arithmetic techniques is now seen as outdated and unsuitable for the educational demands of 21st-century students. (Saltrick, et al., 2011; Jackson, Kehayes, Li, Perkins, & Stewart, 2012). Therefore, incorporating technology into the educational process is crucial, serving as an intervention method in education. Furthermore, it plays a pivotal role in achieving learning objectives and enhancing the teaching and learning process (Voogt, 2008). With this context in mind, the article seeks to assist educators in employing impactful pedagogy for teaching logarithmic functions, emphasizing problem-solving skills and capabilities through a technology-driven approach.

2. Literature Review

Global research indicates that incorporating technology, particularly GeoGebra, in mathematics education yields positive outcomes in student performance. In a study by Arbain and Shukor (2015) focused on mathematics instruction, the findings demonstrated that employing GeoGebra as an intervention led to an enhancement in students' motivation and confidence in learning mathematics (Arbain & Shukor, 2015). Choi (2010) pointed out that GeoGebra software has a positive effect on students' motivation to learn and longer-term knowledge retention in students if they use it in the learning process (Choi, 2010). On the other hand, Shadaan and Eu (2013) contend that GeoGebra proves to be a valuable instrument for enhancing the instruction and comprehension of geometry. The study's findings underscore the affirmative impact of GeoGebra, as it serves to inspire students in their pursuit of learning geometry (Shadaan & Eu, 2013; del Cerro Velázquez & Morales Méndez, 2021).

Zulnaidi and Zamri's (2016) research revealed that students of various proficiency levels exhibited improved conceptual understanding in the subject of functions through the use of the GeoGebra program. This indicates that GeoGebra has a beneficial impact, enhancing both conceptual comprehension and procedural proficiency in mathematical problem-solving. High-performing, average-performing, and low-performing students, who were taught the concept of functions through the GeoGebra program, demonstrated an enhancement in their performance across the board. The program is specifically engineered to make abstract mathematical ideas accessible to users of varying levels of proficiency (Zulnaidi & Zamri, 2016).

Also, the study by Nzaramyimana (2021) research emphasized the efficacy of GeoGebra in promoting active engagement, improving performance, and stimulating students' enthusiasm for mathematics learning. The study underscored how GeoGebra can be a highly effective tool for comprehending exponential and logarithmic functions. The findings demonstrated that a substantial number of students acquired a deeper understanding of these topics, as evidenced by the questionnaire results indicating heightened interest and engagement (Nzaramyimana, 2021). Regarding the use of technology in mathematics education, Drivers, Boon and Van Reeuwijk (2010) delineated three instructional roles of technology: serving as a mathematical tool, providing a platform for skill practice, and offering an arena for conceptual development. For instance, in the case of graphing with GeoGebra, the emphasis lies on the end result rather than the intricacies of the graphing process. Regarding technology's function as a skill-practicing environment, it serves to enhance users' proficiency in executing mathematical operations (Drijvers, Boon, & Van Reeuwijk, 2010).

3. Method

3.1. Purpose of research

Logarithmic functions are important functions in science, mathematics, engineering, and economics. These functions are employed to represent diverse phenomena observed in the physical world. Logarithmic functions are fundamental mathematical principles that hold pivotal positions in advanced mathematics. Through graphic presentation, we can notice many phenomena a during visual presentation. However, it is noticed that the introduction of these functions is causing serious difficulties to students. In this study, we will try to give some results on how to use the GeoGebra program in teaching practice to address topics for presenting and reviewing logarithmic functions. Therefore, in this study, we aim to investigate the role of technology, respectively GeoGebra in the teaching and sustainable learning of logarithmic functions.

3.2. Research question

What are the attitudes of students about using GeoGebra to learn logarithmic functions? What is the added value of using GeoGebra activities in teaching and learning logarithmic functions?

3.3. Hypothesis

H_1: There is a statistically significant difference in the student's performance results of the experimental group compared to the control group in learning the logarithmic functions.

H_2: There is a statistically significant difference in the performance results of the students of the experimental group in the post-test compared to the pre-test after the activities developed with GeoGebra for logarithmic functions.

H_3: There is a statistically significant correlation between the development of activities based on the action plan of the experimental group to a positive effect on students' satisfaction to learn logarithmic functions.

3.4. Design of the study

To achieve the goals of the research, the mixed method was used as the main research methodology in this study. The study used an action research approach to investigate the role of GeoGebra in teaching and learning logarithmic functions. The choice of action research approach was made precisely because this approach is directly related to the practical solutions to the problems faced by teachers in their teaching practices. Vula (2015) shows that when one or more teachers intervene themselves to make changes in teaching practices and at the same time systematically gather facts about the effect of those changes, analyze and reflect on the results found, they are actually dealing with ' action research ' (Vula, 2015). Action research has been selected for this study as it involves practices that are investigated in the learning process and then to discover to make improvements. Our engagement in this action research will help improve teaching, and discover and develop an approach that can be used to assist students in a consistent understanding of logarithmic functions.

3.4. Participants

The research was conducted in the school year 2021/2022 at the high school of music "Lorenc Antoni" in Prizren / Kosovo. The sample is represented by the students of IX grades, from parallels XI-1, XI-2, and XI-3 with a total $(n = 37)$ student. The sample is selected with the non-probabilistic method which is a deliberate sample, treating the students of the experimental group with the integration of GeoGebra in the learning of logarithmic functions. As a sample for the experimental group are selected $(n = 19)$ student, while for the control group are selected $(n = 18)$ student.

3.5. Data collection

In this study, a questionnaire was used to collect data to understand students' attitudes about integrating GeoGebra into learning logarithmic functions, and a test to measure student achievement in these topics. The study used the action research approach through action plan intervention. Quantitative and qualitative data were used in this study. Quantitative data were collected using diagnostic tests, while qualitative data were collected through student reflection through questionnaires.

Tests are compiled before and after the test. Before and after the test was performed in the experimental and control groups. Prior to the test was conducted in both groups to determine the level of student achievement. The same tasks were used for both groups, where before the test there were 10 tasks related to exponential functions. Since exponential functions are related to logarithmic ones it was reasonable to look at student achievement in this topic explained earlier. In the teaching period during the implementation of the summer plan, the experimental group was treated using GeoGebra and the control group was treated with the traditional teaching method, where no technology tools were used in the control group. After this phase, the test was performed for both groups, with 10 tasks related to logarithmic functions.

The questionnaire as another data collection tool was used to analyze students' satisfaction with the role of GeoGebra in learning logarithmic functions. This questionnaire, in the first part contains the personal information of the students, while in the second part contains 7 closed questions based on the Likert scale with five points, and in the third part contains three open questions to understand the attitudes. students' insights into using GeoGebra in math. The statistical program for social sciences SPSS was used to analyze and interpret the quantitative data collected from tests and questionnaires. Whereas, qualitative data are analyzed narratively.

3.6. Action Plan

The action plan was based to meet the desired learning outcomes set out in the Kosovo Curriculum Framework. Groups of students were given an orientation regarding the course of the study. Both the control and experimental groups learned the same topics about logarithmic functions. However, a different teaching approach was used. For the control group the conventional way of teaching was applied, while for the experimental group a technology application is used using the GeoGebra program. The action plan lasted for almost three weeks in the school year 2021/2022. Initially, the action plan identified the problems that were emerging in the students, and this was justified by previous lessons on exponential functions. Subsequently, a pre-test was conducted to test the consistent knowledge of students who had learned about the review and presentation of exponential functions. As mentioned here, the action plan was developed for the students of the experimental group, who were treated by integrating the GeoGebra program into the classroom learning process to explore concepts related to the intuition of representing logarithmic functions. The activities developed by the action plan are as follows.

Activity 1: The main purpose of this activity is to present and analyze in a coordinate system the position of the graph of the logarithmic function when changing the value of the logarithm basis. Also, in this activity the domain of the logarithmic function is examined, where the value of x is seen to be $(x > 0)$):

$f(x) = \log_2 x$ b) $f(x) = \log_3 x$ c) $f(x) = \log_4 x$

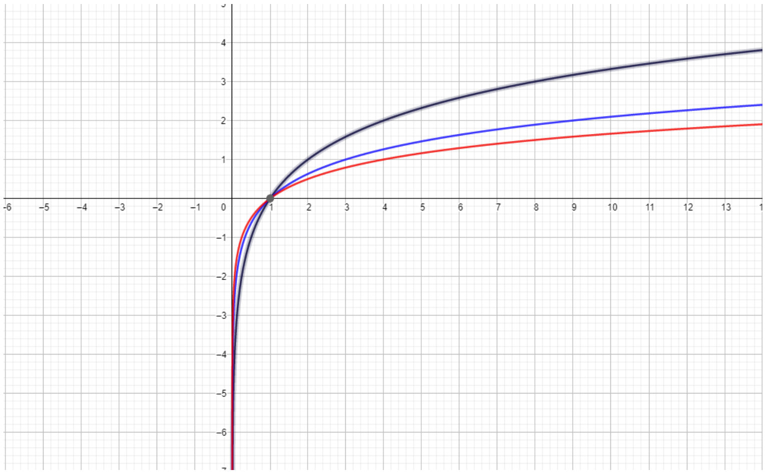

Figure 1. Graph of logarithmic functions with base 2

Activity 2: In this activity the position of the graph of the logarithmic functions of the form is examined and discussed $f(x) = \log_2 x + a$, by changing the values of the parameter a:

$f(x) = \log_2 x + 1$ b) $f(x) = \log_2 x + 2$ c) $f(x) = \log_2 x - 1$

Activity 3: This activity examines and discusses in a coordinate system the position and monotonicity of logarithmic functions, i.e., increasing and decreasing the graph of logarithmic functions:

$f(x) = \log_2 x$ b) $f(x) = \log_{\frac{1}{2}} x$

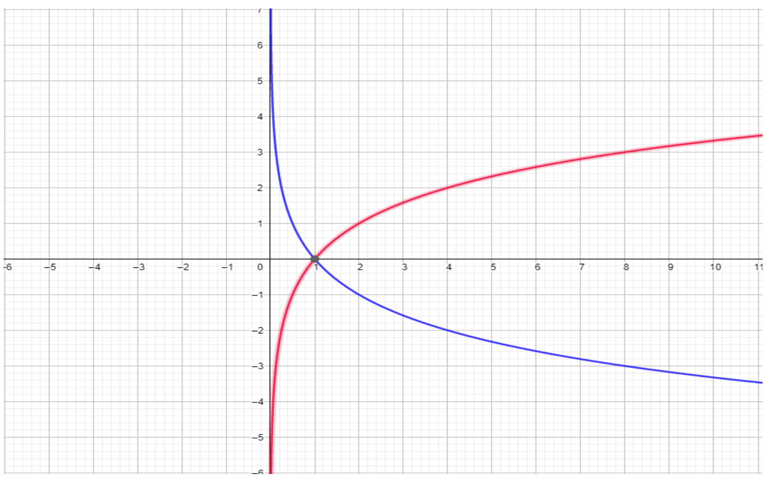

Figure 2. Graph of logarithmic functions with base 2 and $\frac{1}{2}$

Activity 4: The purpose of the activity is for students to find in which quadrant of the coordinate system lies the graph of the logarithmic function $f(x) = \log_2 x$.
Activity 5: Students in this activity should analyze and define the graph of the function $f(x) = \log_b x$ presented by GeoGebra that for the base values b the monotonicity of the function changes, where for $b > 1$ it is increasing, while for the values of $0 < b < 1$ the function is decreasing.
Activity 6: During the review and graphical presentation of the logarithmic function of the shape $y = c \cdot \log_b(x - k) + d$, students analyze the role of parameters b, c, k and d how they affect the change of the graph extension of the logarithmic function.
Activity 7: The activity envisages the review and graphical representation of the logarithmic function $y = \log_2 x$ at points:

$x = 0$ b) $x = 1$ c) $x = 2$ d) $x = 3$ e) $x = 4$

Activity 8: From the graph of the logarithmic function presented by GeoGebra students in this activity try to write the logarithmic function, reasoning, and arguing their thoughts according to the rules of logarithmic functions.
After the completion of the activities in the experimental group and after the explanation of these learning units in the control group with the traditional method, a post-test was compiled. After the test, we aimed to understand whether the treatment of students with technology had an impact or not. After the test, it was distributed to both groups and then the results obtained from this test were analyzed compared to the pre-test.
Finally, a questionnaire was compiled for the experimental group. Where his goal was to understand the deeper satisfaction about using GeoGebra for logarithmic function topics.

4. Results

Descriptive statistical results of the first test for assessing students' knowledge of exponential functions of previously learned topics, both for the experimental group and for that control are presented in the table below:

Table 1. Pre-test results

		Total N	Minimum	Maximum	Mean	Median	Standard Deviation	Standard Error of Mean
Group	Control	18	20.0	80.0	44.4	45.0	17.6	4.1
	Experimental	19	20.0	70.0	46.3	50.0	18.3	4.2

Results from Table 1. **Pre-test results** indicates that the control group, consisting of 18 participants, obtained an average score of 44.4 in the pre-test, whereas the experimental group, comprised of 19 participants, achieved an average score of 46.3. A t-test for independent samples was conducted at a 95% confidence level to assess if there was a noteworthy disparity between the mean scores of the two groups in the pre-test. These results are presented in the table below:

Table 2. T-test results from pre-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre-test	Equal variances assumed	.111	.741	-.317	35	.753	-1.8713	5.9066	-13.86	10.1196
	Equal variances not assumed			-.317	34.994	.753	-1.8713	5.8996	-13.84	10.1056

According to the results of Table 2. **T-test results from pre-test**, the Levene test had a value of .111 where it is shown to be greater than .05, thus assuming that the knowledge of the control and experimental group students is equal. The reciprocity test value for the two groups was 0.753 for both cases, which means that the difference in measurement is not statistically significant. Therefore, the findings show that there is no statistically significant difference between the mean value of the control group and the experimental one based on the results of the first tests when assessing the knowledge of exponential functions. This shows statistically that students in the control and experimental group had similar levels of knowledge on these topics at the beginning of the research. Therefore, any difference in later results can be attributed to the action plan intervened with the GeoGebra program.

Descriptive statistical results of the post-test for assessing students' knowledge of the logarithmic functions of the control group learned by the traditional teaching method and the experimental group treated with the action plan are presented in the table below:

Table 3. Post-test results

		Total N	Minimum	Maximum	Mean	Median	Standard Deviation	Standard Error of Mean
Group	Control	18	20.0	60.0	38.9	40.0	13.7	3.2
	Experimental	19	20.0	80.0	56.3	60.0	21.4	4.9

Results from **Error! Reference source not found.**:

The descriptive statistics for both groups in evaluating students' knowledge of logarithmic functions in the post-test are as follows: For the control group, the mean score was 38.9, with a standard deviation of 13.7 and an average margin of error of 3.2. In contrast, the experimental group exhibited a mean score of 56.3, along with a standard deviation of 21.4 and an average margin of error of 4.9. The result according to the averages of the students after the test shows that the results of the students of the experimental group are significantly higher than those of the control group.

A t-test for independent samples was conducted at a 95% confidence level to assess whether there existed a notable distinction between the means of the two groups in the post-test. These results are presented in the table below:

Table 4. T-test results from post-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Post-test	Equal variances assumed	4.821	.035	-2.933	35	.006	-17.4269	5.9413	-29.4885	-5.3653
	Equal variances not assumed			-2.968	30.800	.006	-17.4269	5.8724	-29.4068	-5.4470

The results from the t-test are presented in **Error! Reference source not found.**. The Levene test statistic, at 0.035, falls below the significance threshold of 0.05. This indicates that it cannot be assumed that the variances between the control and experimental groups are equal concerning the outcomes following the implementation of the action plan in the experimental group. Moreover, the two-tailed value is below 0.05, signifying that the difference in means is statistically significant. These results suggest that students in the experimental group demonstrated higher performance after the implementation of the action plan with GeoGebra in the subject of logarithmic functions compared to students in the control group, who did not undergo this intervention.

Comparison of results within the experimental group between before and after the test are presented below:

Table 5. Comparison of pre-test and post-test results

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic

Pre-test	19	50.0	20.0	70.0	46.316	4.2032	18.3214	335.673
Post-test	19	60.0	20.0	80.0	56.316	4.9091	21.3985	457.895

Analysis of results by **Error! Reference source not found.** shows that the results are 10% higher in the post-test than in the pre-test in the experimental group. The outcomes of these assessments indicate that the differences observed in the instruction and comprehension of logarithmic functions can be attributed to the integration of the GeoGebra program.

After analyzing the existence of a relationship between activities and student satisfaction during the implementation of the action plan with GeoGebra, it is worth looking at the intensity of their relationship, for which we used Pearson correlation as in the table below:

Table 6. Pearson Correlation

Control Variables			Students' perceptions	Post-test
Pre-test	Students' perceptions	Correlation	1.000	.442
		Significance (2-tailed)	.	.007
		df	0	34
	Post-test	Correlation	.442	1.000
		Significance (2-tailed)	.007	.
		df	34	0

Results from **Error! Reference source not found.** show that there is a correlation with .442 and a significant is .007, which means that there is a positive and moderate relationship between the activities developed with the action plan and students' satisfaction in learning logarithmic functions.

From the research results, we see that during the survey with students of the experimental group participated 52.6% were females and 47.4% males, of which 68.4% had average knowledge of technology use and 31.6% advanced knowledge of technology use. With this, we see that the study had a good distribution of participants both in terms of gender and skills of using technology, as this group was exposed to the integration of technology in the learning process.

The results of the questionnaires show that 94.7% of the participants agree that the demonstration of logarithmic functions using GeoGebra has helped them to understand logarithmic functions more easily and when presenting logarithmic functions with GeoGebra they have noticed any changes that appeared in the graph, while only 5.3% have no position on these allegations. The results also show that 78.9% of participants say that the activities developed for logarithmic functions were more attractive with GeoGebra and prefer that math lessons be conducted with GeoGebra, while another 21.1% do not have the same attitude. Therefore, GeoGebra motivated students to interact, and also the concept of logarithmic functions was developed from visual materials.

Table 7. Descriptive Statistics of students' attitudes

	N	Range	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Student attitudes	19	.00	2.0000	.00000	.00000	.000
Valid N (listwise)	19					

Based on the results of **Error! Reference source not found.** we are noticing that all participants have positive attitudes about using GeoGebra to learn logarithmic functions. In other words, using GeoGebra to explain topics from logarithmic functions.

The participants emphasized that the advantages of GeoGebra were that the tasks are easier to understand and easier to solve. Another student points out that this was a new way developed with technology and that we noticed any changes that appeared in the graph. They show that the learning units are easier to remember, where the lesson is more attractive and in favor of all students regardless of the level of knowledge. Therefore, we can say that GeoGebra had many advantages, which these advantages were able to help introduce logarithmic functions and have interaction between teacher and students in the learning process in an attempt to understand the topic covered. However, students also highlighted the disadvantages of integrating GeoGebra into the learning process. In addition to subjective reasons, they pointed out that there are also objective factors that affect the choice and effectiveness of program use, including lack of facilities, lack of computers, lack of necessary resources, lack of training, and lack of support from other teachers. However, the research results showed more advantages that the GeoGebra program had, compared to the disadvantages.

Among the students' additional comments about the use of the GeoGebra in learning logarithmic functions was that students have shown positivity towards the program and seek to use it more often when elaborating mathematical concepts. Participants say that the use of GeoGebra has a much greater effect in explaining logarithmic functions alongside the traditional teaching method. Comments were also that, the GeoGebra program motivates students and encourages them to participate in the classroom activity while introducing these functions.

5. Discussion

The current study highlighted the effectiveness of GeoGebra in enhancing students' sustainable learning, performance, and attitudes to learning mathematical concepts. The research underscored the effectiveness of utilizing GeoGebra for the acquisition of logarithmic function concepts.

Thus, the results of our study from the data collected through the student attitudes questionnaire on the role of GeoGebra in the sustainable learning of logarithmic functions showed that their interest has increased. Also, the results show that students' attitudes are positive about the integration of the GeoGebra in the learning process in the subject of mathematics, this is evidenced by the results from **Error! Reference source not found.**. These findings are also consistent with the findings of the authors Arbain and Shukor (2015) where they show that students have positive perceptions about GeoGebra software in terms of motivation, confidence and enthusiasm. Therefore, from all this we can give an answer to the first question posed that students' attitudes are very positive about the use of the GeoGebra in learning logarithmic functions.

Our study's results align with the conclusions drawn by Philip, Wozney, and Venkatesh (2006), Ertmer and Ottenbreit-Leftwich (2010), and Waxman, Connell, and Gray (2002). These authors found that students who incorporate technology into their learning experience exhibit enhanced educational achievements compared to those who do not utilize technology (Philip, Wozney, & Venkatesh, 2006; Ertmer & Ottenbreit-Leftwich, 2010; Waxman, Connell, & Gray, 2006). Also, the findings suggest to a small extent that the students of the experimental group after implementing the GeoGebra action plan were able to analyze and interpret logarithmic functions more deeply for solving problems. The findings also show that GeoGebra was an excellent motivational tool, as student satisfaction increased when the GeoGebra was integrated to improve the learning process. Therefore, from these results we can give an answer to the second research question that the added value that brings the use of activities with GeoGebra in teaching and learning logarithmic functions was the improvement of results, student motivation, enjoyment of use, creativity of problem solving and positive attitudes about math lessons.

Our findings are similar to Nzaramyimana (2021) findings on increased learning and performance. Therefore, according to our results from **Error! Reference source not found.** and t-test by **Error! Reference source not found.**, we can affirm the initial research hypothesis: there exists a statistically significant disparity in the academic performance of students between the experimental and control groups in their understanding of logarithmic functions. These results are in favor of the experimental group treated with the action plan.

Our results relate to the findings of Saha, Ayub and Tarmizi (2010), as well as Shadaan and Eu (2013) who also found that the use of GeoGebra enhanced student performance in teaching mathematics. In general, it can be concluded that students who have used the GeoGebra program have gained higher knowledge in the post-test than those in the pre-test. The results are presented statistically in **Error! Reference source not found.**. Therefore, based on these discoveries, we can validate the second hypothesis: there is a statistically significant contrast in the performance outcomes of students in the experimental group between the post-test and pre-test, following the activities conducted with GeoGebra for logarithmic functions. This is proving that post-test scores were higher compared to pre-test scores in this study group.

The results of the study show that there is a positive and moderate relationship displayed in the results from **Error! Reference source not found.**. This finding is supported by the study of Doğan and Içel (2011) where it was observed that technology activities promote higher level thinking skills and had a positive effect on motivating students to learn (Doğan & Içel, 2011). Therefore, from our findings we can confirm the last hypothesis that there is a statistically significant correlation between the development of activities based on the action plan of the experimental group to a positive effect on students' satisfaction to learn logarithmic functions.

Finally, this research has shown that the GeoGebra program has a positive impact on student achievement on the topic of logarithmic functions. According to this study, it's important to note that the conclusions drawn from this research may not be broadly applicable to students across various schools and countries. Instead, they pertain specifically to students in schools with comparable characteristics to those considered in this study.

6. Conclusion

In teaching and learning logarithmic functions, it is often understood that students still lack cognitive and conceptual skills in understanding the presentation of these topics. So, from the study, we can conclude that the use of GeoGebra in the teaching process in the subject of mathematics has greatly improved the ability of students to visualize the presentation of some logarithmic functions in a coordinate system. From these visualizations the students were able to see any changes for each function presented.

GeoGebra was a pedagogical tool for fostering students' understanding and satisfaction of topics from logarithmic functions. Therefore, the use of GeoGebra software to teach topics related to logarithmic functions had played an important role in this study. The approach was effective as it resulted in improved student performance when graphing logarithmic functions. The experimental group that had implemented the action plan performed significantly better after the intervention compared to the results of the pretest and control group.

Using GeoGebra in the math teaching process helps students develop basic math skills. Well-organized and well-planned support with this program, as well as ample activities helps many students to solve various problems around the topics of logarithmic functions. Students were able to experience a practical method of learning which had a positive effect on their ability to better understand logarithmic functions rather than simply being passive learners. We can broadly say that technology will improve education, making teaching and learning approaches more convenient, attractive and sustainable for students.

Utilizing the GeoGebra program can establish a conducive learning setting, given its highly dynamic nature in educational technology. It possesses the capacity to assist students in their exploration through activities such as examples, review, presentation, calculation, modeling, and reflection.

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Bibliography

Arbain, N., & Shukor, N. A. (2015). The Effects of GeoGebra on Students Achievement. *Procedia-Social and Behavioral Sciences, 172*, 208–214.

Choi, K. (2010). Motivating students in learning mathematics with GeoGebra. Annals. *Computer Science Series, 8*(2). 65-76.

Doğan, M., & Içel, R. (2011). The role of dynamic geometry software in the process of learning: GeoGebra example about triangles. *International Journal of Human Sciences, 8*(1), 1441-1458.

Drijvers, P., Boon, P., & Van Reeuwijk, M. (2010). Algebra and technology. In P. Drijvers (Ed.), Secondary algebra education: Revisiting topics and themes and exploring the unknown. Rotterdam, the Netherlands: *Sense Publishers*, 179-202.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of research on Technology in Education, 42*(3): 255-284.

Holliday, B., Cuevas, G. J., Moore-Harris, B., Carter, J. A., Marks, D., Casey, R. M., Hayek, L. M. (2008). *Algebra 1*. New York: Glencoe/McGraw Hill.

Jackson, T., Kehayes, J., Li, J., Perkins, D., & Stewart, V. (2012). Teaching and learning 21st century Skills: Lessons from the Learning Sciences. *Apera Conference, Sydney*, 1-35.

Makgakga, S., Sepeng, P. (2013). Teaching and Learning the Mathematical Exponential and Logarithmic Functions: A Transformation Approach. *Mediterranean Journal of Social Sciences, 4*(13): 177-185

Mushipe, M. (2016). *Effects of Integrating Geogebra into the Teaching of Linear Functions on Grade 9 Learners' Achievement in Mopani District, Limpopo Province.* University of South Africa.

Nzaramyimana, E. (2021). Effectiveness of GeoGebra towards Students' Active Learning, Performance and Interest to Learn Mathematics. *IJMCR, 9(*10): 2423-2430.

Phan-Yamada, T., & Man, S. W. (2018). Teaching Statistics with GeoGebra. *North American GeoGebra Journal, 7*(1), 14-24.

Philip, C., Wozney, L., & Venkatesh, V. (2006). Implementing Computer Technologies: Teachers ' Perceptions and Practices. *Journal of Technology and Teacher Education, 14*(1), 173-207.

Saha, R. A., Ayub, A. M., & Tarmizi, R. A. (2010). The effects of GeoGebra on mathematics achievement: Enlightening Coordinate Geometry learning. *Procedia - Social and Behavioral Sciences, 8*, 686–693.

Saltrick, S., Hadad, R., Pearson, M., Fadel, C., Regen, B., & Wyan, J. (2011). 21st century skills map. In XX (Eds.). Partnership for 21st century skills. *Washington: Partnership for 21st Century Skills*, 1-34.

Shadaan, P., & Eu, L. K. (2013). Effectiveness of Using GeoGebra on Students' Understanding in Learning Circles. *The Malaysian Online Journal of Educational Technology*, *1*(4), 1–11.

Velázquez, F., Méndez, G. (2021). Application in Augmented Reality for Learning Mathematical Functions: A Study for the Development of Spatial Intelligence in Secondary Education Students. *Mathematics*, *9*, 369.

Voogt, J. (2008). IT and Curriculum Processes: Dilemmas and Challenges. *International Handbook of Information Technology in Primary and Secondary Education*, 117-132.

Vula, E. (2015). Hulumtimi në veprim - Udhëzime praktike për hulumtimet në klasë. *Basic Education Prigram*, 1-96.

Waxman, H. C., Connell, M. L., & Gray, J. (2006). A Quantitative Synthesis of Recent Research on the Effects of Teaching and Learning with Technology on Student Outcomes. *North Central Regional Educational Laboratory*, 5-28.

Zulnaidi, H., & Zamri, S. A. (2016). The Effectiveness of the GeoGebra Software: The Intermediary Role of Procedural Knowledge On Students' Conceptual Knowledge and Their Achievement in Mathematics. *EURASIA Journal of Mathematics Science and Technology Education*, *13*(6):2155-2180.