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The Effect of GeoGebra Software in Calculus for Mathematics Teacher Students

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Abstract

The objectives of these mixed methods were to 1) improve students' performance in calculus by using GeoGebra software and 2) investigate students' experiences with and perspectives on using GeoGebra software in calculus. The participants were 58 mathematics teacher students at a university in Thailand. The instruments in this study were a test; this was called the Calculus Achievement Test (CAT), which consists of limits and continuity; a derivative of function; and its application; and a questionnaire with an interview with a student. The statistics for qualitative data were gathered from instruction; we used percentages, mean scores, standard deviations, and a one-sample *t*-test; while quantitative data was gathered

from students' reflections and interviews. The results showed: 1) the results of the one-sample *t*-test show that using GeoGebra Software in Calculus is effective in students' performance; 2) the data, the quantitative findings show that students were more interested and excited during the intervention. Students could better show their creativity and learn about themselves because of the intervention. Teaching calculus with GeoGebra embedded is a good and effective way to do things. The finding shows a good chance of developing technology-integrated math curricula for teaching and learning calculus.

Keywords: GeoGebra, Calculus, Mixed-methods, Mathematics teacher students

1. Introduction

1.1 Introduce the Problem

Calculus is an important branch of math because it is used so often in modern science and technology (Çekmez, 2020). It's a springboard towards further study of advanced arithmetic. Calculus is an important part of many scientific fields, such as chemistry, biology, physics, economics, computer graphics, informatics engineering, and many more. Calculus is used in the study of a wide range of physical ideas, including those related to temperature, sound, light, electricity, motion, acoustics, astronomy, dynamics, relativity, and electromagnetic. Calculus is often used in the field of chemistry to predict things like the rate of radioactive decay and the speed of chemical reactions. It is a crucial component in calculating birth and mortality rates in biology. The concept is used in economics to determine marginal costs and revenues. Computer graphics employs mathematics for ray-tracing and lighting approaches. Calculus is an important part of the field of engineering informatics, which is used to develop artificial intelligence, which is the intelligence that a machine shows (Fatimah, 2019).

Even so, many reports have shown that students have trouble understanding what calculus is all about. Some of the trickiest ideas include derivatives and integrals. Calculus is a subject that is generally not well understood by students (Carnell et al., 2018; Çekmez, 2020; Dawkins & Epperson, 2014). Problems originate from a variety of sources, including 1) a lack of background knowledge (Carnell et al., 2018); 2) a lack of ability to make connections among ideas like the set theory of real, relations, number systems, limit continuity, differential functions, and differential applications; 3) a lack of ability to perform arithmetic and algebraic operations on functions; 4) a lack of ability to perform verbal procedures verbal relating to the application of functions and derivatives; 5) a lack of ability to reason logically (Case & Speer, 2021); and 6) difficulty in providing a visual description of the subject. Fatimah (2019) found that the students had difficulty learning how to graphically describe functions and how to determine their domain and range. They also have trouble with more complicated algebra tasks like finding tangents, parallel lines, and lines that cross each other. Therefore, many students struggle with understanding calculus (Yerizon & Tasman, 2021).

1.2 Explore the Importance of the Problem

Many strategies have been tried to help these youngsters succeed. A lack of computers, according to Kovács, Recio, Richard, Van Vaerenbergh, and Vélez (2022), limits the potential benefits of technology in the classroom. While the goal of incorporating technology into

education is to facilitate and improve students' ability to learn new material, the high initial investment and ongoing support needed to make use of such tools have slowed their adoption. According to Kumar, Shet, and Parwez (2022), the advantages to teachers are crucial to the effectiveness of incorporating technology into the classroom. Many researchers have looked at how technology may be used to help students learn mathematics, but they have come to wildly contrasting conclusions on whether or not this actually helps. In the case of mathematics, for example, studies by Büchel, Jakob, Kühnhanss, Steffen, and Brunetti (2022) concluded that technological intervention did not yield appreciable gains for students.

The use of technology in mathematics education, however, has been criticized by a number of researchers (Kovács et al., 2022; Livy, Muir, Murphy, & Trimble, 2022; Naidoo, 2022). However, different research found that incorporating technology into the classroom is one of the most effective ways to improve students' performance in a variety of mathematical courses, including calculus (Eyyam & Yaratan, 2014). Using technological means to further one's education is a worthwhile endeavor. Technology, such as computers and software, plays an increasingly important role in the curriculum. Integrating technology into the classroom provides students with access to a variety of learning strategies (Hohenwarter, Hohenwarter, Kreis, & Lavicza, 2008). The use of technology has been shown to improve not just one's ability to solve mathematical problems, but also one's capacity for original thought (dos Reis, Miranda, & Pereira Filho, 2019; Xu, 2016). supports the development of logical and arithmetic reasoning (Tatar & Zengin, 2016). A technology-supported environment (TSE) for studying calculus with a focus on using GeoGebra for Riemann sums (Caglayan, 2014).

1.3 Describe Important GeoGebra Software in Mathematics

Tatar and Zengin (2016) represent GeoGebra, an alternative strategy for overcoming calculus problems. GeoGebra was designed with better educational outcomes in mind. It is lively, user-friendly, open-source, student-focused, and interactive. It's had a significant impact on the use of ICT in arithmetic classrooms (Clark & Lee, 2019). All conic sections may be built in GeoGebra, along with points and lines. Particular capabilities are provided, including those for locating important points in functions and for calculating derivatives and integrals of a given function with a single line of input. This makes it a viable alternative for many kinds of mathematical object displays (Ziatdinov & Valles Jr, 2022). Mathematical concepts are much easier to grasp and make sense of when represented visually (Dahal, Pant, Shrestha, & Manandhar, 2022). Colorful figures, drawings, diagrams, and graphs are more likely to be used by students and teachers. It is critical to visualize a mathematical problem in order to fully comprehend it and progress toward a solution (Kajander & Avoseh, 2022).

In order to assist students in better understanding mathematics, GeoGebra was created. Draggable "free" items on the plane and adjustable slides make it simple for students to adjust values. Using a strategy involving the manipulation of things, students may produce changes and gain insight into the effects those changes have on the items upon which they depend. There was a time when students learned to solve issues by actively exploring mathematical relations (Yerizon & Tasman, 2021).

1.4 State Hypotheses and Their Correspondence to Research Design

Because this is an important topic, the goals of this study, which are based on its importance, are to 1) improve students' performance in calculus by using GeoGebra software and 2) investigate students' experiences with and perspectives on the use of GeoGebra software in calculus. The *t*-test was carried out on the sample in all research classes of a calculus course with as many as 48 students. The hypotheses in this study are:

H_0: The GeoGebra software is not effective in students' performance in calculus.

H_1: The GeoGebra software is effective in students' performance in calculus.

The decision-making data for the one-sample *t*-test are:

(1) If the value is Sig. (2-tailed) < 0.05, then H_0 is rejected.

(2) If the value is Sig. (2-tailed) > 0.05, then H_0 is accepted.

2. Method

2.1 Participants

In the first semester of the 2022 academic year, there were 283 undergraduate students majoring in mathematics enrolled at one university in Thailand. One group of undergraduate students in mathematics made up the participants of the study. In total, 48 students were selected for the study, with the number of these students depending on the department's capability. The students who took part in the study were chosen by a lottery or a simple random sampling method.

2.2 Research Instrument

2.2.1 Instruments

The instruments in this study were: 1) a test (a word problem); this was called the Calculus Achievement Test (CAT); it consists of limits and continuity; derivative of function; and its application, which is a word problem (essay test); and 2) a questionnaire form. There was also an interview and a questionnaire with questions that couldn't be answered in more than one way. On the other hand, a word problem gives the teacher an opportunity to assess what the students understand and don't know (Morgan, 2007). There are 18 questions in the CAT test, and there is a five-level scoring scale: (5-the student completes all-important task components and communicates ideas clearly; 4-the student completes most important task components and communicates ideas clearly; 3-the student completes some important components of the task and communicates those clearly; 2-the student demonstrates only a basic understanding; 1-blank/no response) (Kubiszyn & Borich, 2016) with a maximum score of 90 points. This is closely related to investigating the student's competence in a certain domain. So, the researcher could tell how well the students knew calculus before and during the study by combining the two types of questions. The validity and reliability of each instrument are discussed in the following section. QDA Miner and Microsoft Excel Spreadsheet Software were used for data analysis

2.2.2 Validity of the Instrument

According to Thompson (2013), validating a test is a never-ending cycle of checking the validity of assumptions made based on test results. A panel of experts in calculus and mathematics education (with a master's degree or Ph.D. in mathematics education) was supplied with the exam, the GeoGebra-oriented lesson plan, and the course outline to confirm content validity in this study. Together with my superiors, there were a total of five mathematicians who took part. Experts also double-checked that the interview tools were compatible with a set of research questions, and the table of a specification makes sure that the information is correct.

2.2.3 Reliability of Tests and Questionnaires

The study included a test that served as both a baseline and an outcome measure. The researcher got the test questions from the lesson plan, and both math experts and the researcher's boss confirmed that they were correct (Cronbach, 1990). The validity of a test is how well it measures what it says it measures based on common standards like the content of a given textbook and course outline. In its simplest form, content validity is how well a test measures the concepts it claims to measure. Pallant and Manual (2007) say that validation can't be decided with absolute certainty and needs to be looked at by experts in the field. To ensure the rigor of the qualitative results, the researcher took into account the dependability, credibility, transferability, and confirmability of the qualitative data (Armour & Williams, 2022). Research professionals reviewed the interviews to ensure their accuracy.

During the pilot study, a test and a questionnaire for students were administered to 30 participants. This was done to make sure that questionnaires were reliable on the inside and to find out how well the questions fit together. To assess whether the CAT test score was reliable, Cronbach's alpha value and inter-item correlations were computed to examine the deficit in items. The Cronbach alpha value for CAT was found to be 0.86, with Index of Item-Objective Congruence (IOC) values ranging from 0.67 to 1.00, difficulty values between 0.56 and 0.76, and discriminant indices between 0.30 and 0.49.

2.3 Data Analysis and Interpretation

2.3.3 Research Design

In this study, the researchers used a mixed-methods approach. In mixed methods research, several approaches are used: in this case, a combination of qualitative and quantitative approaches. The quantitative data in the study was analyzed using the *t*-test, which was used in this study with a one-group post-test-only design (Edmonds & Kennedy, 2017). To find out what the students thought about the study's tools, QDA Miner software was used to look at the qualitative data using narrative techniques. Then a test is given to see the impact of using the GeoGebra software on students' mathematical reasoning abilities (in Calculus). The criteria for students' calculus performance values can be seen in Table 1.

Table 1. Criteria for students' performance in calculus

Grade	Percent of the Score (The Grade Interval)	Criteria
A	80-100	Excellent
B+	75-79	Very Good
B	70-74	Good
C+	65-69	Above Average
C	0-64	Average
D+	55-59	Below average
D	50-54	Poor
F	0-49	Fail

Note. The GeoGebra program helps students do better in Calculus if they get a score of 70%, which shows that they have met the criteria and passed.

A summary of data analysis techniques can be seen in Table 2.

Table 2. Summary of data analysis techniques

Mixed-Method Design	
The quantitative phase of the study	**The qualitative phase of the study**
Research question 1: How does the level of proficiency in calculus compare to students taught using GeoGebra?	**Research question 2**: What are students' experiences and perceptions about learning? Can I use GeoGebra to do calculus?
Theoretical Framework. Vygotsky's Theory. Analysis techniques. The narrative method was used to find out what the participants thought about GeoGebra and the fact that it and other programs were available at the university. Frequency distributions.	

3. Results

In the sections that follow, the results of a study are given based on the research questions:

3.1 Students' Performance in Calculus

The results of the student's performance in Calculus on the one-sample *t*-test using Microsoft Excel Spreadsheet Software can be seen in Table 3 below.

Table 3. The one-sample *t*-test result

One-Sample Test	Test value = 70					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Score	3.50	47	0.001	6.06	2.58	9.55

The one sample *t*-test result shows that using GeoGebra Software teaching in Calculus is effective in students' performance in calculus: t (47) = 3.50, p = 0.001. That means that the GeoGebra embedded instruction is a better way to help students do better in Calculus.

Figure 1 shows that, overall, 70% of the good criteria can be seen, including limit and continuity at 76.70%, which is very good; the function's derivative at 77.87%, which is very good; and its application at 71.28%, which is good.

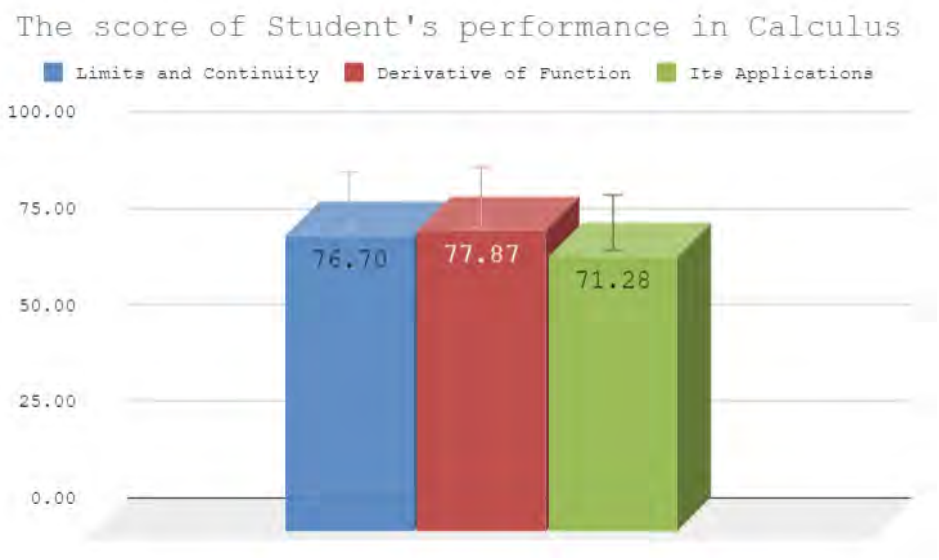

Figure 1. The score of students' performance in Calculus

3.2 Investigate Students' Experiences with and Perspectives on the Use of Mathematical Software (GeoGebra) in Calculus

After considering what students would have to say, instructors adjusted their approaches to boost students' knowledge retention. Their final thoughts, however, were evaluated thematically and synthesized. Through this process, the following student perceptions were established: perceptions towards the benefits of GeoGebra; perceptions towards scaffolding in the classroom; and perceptions towards the learning difficulties of GeoGebra.

Different categories were used to code the thematically studied data so that it could be looked at in-depth. Student categories included: C1, C2, C3, etc. The frequency (f) of a student's participation in a code was calculated as shown in Table 4.

Table 4. Codes for perceptions of GeoGebra categories of students' view

Category	Items	Code	Frequency (f)
Perceptions towards Benefits of GeoGebra (C1)	Why are your perspectives on using GeoGebra to teach calculus so essential? Do you think this is something high school students could use?	Provides better visualization	5
		Increases understanding	4
		Promotes individual and teamwork	5
		Increases interest and motivation	1
		Boosts imagination	3
Perceptions towards scaffolding in the classroom (C2)	What are the advantages and disadvantages of using GeoGebra to learn calculus?	Advantages	5
		Disadvantages	3
	Do you want to tell others about this software and get their feedback on what other courses they should take?	Including the use of other ideas and lessons	5
Perceptions towards the Learning difficulties of GeoGebra (C3)	Could you recommend any math software that has helped you in your studies?	Existing mathematical software	5
	Why do you think mathematical software learning difficulties are integrated into your subjects?	Shortage of time	2
		Lack of skills to manipulate GeoGebra	2

Table 4 reveals the students' perceptions of GeoGebra. The details are as follows:

3.2.1 Perceptions towards Benefits of GeoGebra (C1)

Why are your perspectives on using GeoGebra to teach calculus so essential? Do you think this is something high school students could use?

Five students reported that GeoGebra approaches provided better visualization. Two students'

comments were as follows:

> *Student 2: "Make it more visual and clearer; it may be taught to kids; it is extremely valuable to high school students who are required to study a great deal about linear graphs, dark curves, concave, upturned curves, and the like."*
>
> *Student 3: "The GeoGebra software is a cutting-edge math education platform, and so is GeoGebra, a 3D mathematics education platform." This is very helpful for high school students because it helps them understand better than writing or reading. This is especially true for parabolic."*

Four students reported that GeoGebra's approaches increase understanding. The two students' comments were as follows:

> *Student 2: "Improve its visual appeal and readability so that it may be taught to elementary school children." This is very helpful for high school students who are expected to learn about linear graphs, dark curves, concave, upturned curves, and similar topics."*
>
> *Student 4: "It helps us understand calculus better by showing how the functions change over time on a graph." I also believe that high school students may benefit much from the use of the GeoGebra program, which is available to them regardless of their grade level."*

Five students reported that GeoGebra's approaches promote individual and teamwork. Two students' comments were as follows:

> *Student 4: "Being able to see how a function changes over time is a big help in understanding calculus, and it encourages both independent work and working with others. "I also believe that high school students may benefit much from using GeoGebra, which is available to students of all ages."*
>
> *Student 5: "It's a great tool for high school students because it's simple to use and quick to obtain information."*

One student reported that GeoGebra approaches increased understanding; his comment was as follows:

> *Student 1: "Simplistic and up-to-date It adds variety, which gives the subject greater visual appeal and provides an incentive to learn."*

Three students reported that GeoGebra's approaches boosted their imaginations. Two students' comments were as follows:

> *Student 3: "This cutting-edge platform for teaching math encourages originality and lateral thinking, which helps me understand hard math ideas better."*
>
> *Student 4: "By showing the change visually on a graph, it helps me understand calculus and makes me think creatively."*

3.2.2 Perceptions towards Scaffolding in the Classroom (C2)

What are the advantages and disadvantages of using GeoGebra to learn calculus?

Five students reported that the GeoGebra approaches have advantages. Two students' comments were as follows:

Student 1: "I need the means to double-check my work and get some experience with the problems."

Student 2: "Being able to create a graph and identify its nodes and vertices is the first step toward taking an interest in and learning about the graph." In addition, there are now more functionalities."

Three students reported that the GeoGebra approaches have disadvantages. Two students' comments were as follows:

Student 1: "GeoGebra is not yet at native speed, so learning it will take some time."

Student 3: "If you don't understand the material, you won't be able to make the most of the GeoGebra software."

Do you want to tell others about this software and get their feedback on what other courses they should take?

Five students reported that GeoGebra's approaches included the use of other ideas and lessons. Two students' comments were as follows:

Student 4: "There isn't as much access as there should be, so I want to share, and I also want my friends to teach."

Student 5: "I think GeoGebra would be a good way to learn about abstract ideas in calculus and other math classes."

3.2.3 Perceptions towards the Learning Difficulties of GeoGebra (C3)

Could you recommend any math software that has helped you in your studies?

Five students reported that GeoGebra approaches existing mathematical software. Two students' comments were as follows:

Student 1: "I was fluent in Photomath and QANDA."

Student 4: "I don't know; I was a high school student at the time." Teachers typically don't provide their students with hands-on experience with the software during class."

Why do you think mathematical software learning difficulties are integrated into your subjects?

Two students reported that GeoGebra approaches an existing shortage of time. Two students' comments were as follows:

Student 2: "The learning process is hurried, especially the ideation step."

Student 4: "In my opinion, you need a good chunk of time to put into practice using GeoGebra to fully grasp the idea of limits. However, time was a problem for me when I needed to do things like come up with ideas and study on my own."

Two students reported that GeoGebra approaches a lack of skills to manipulate GeoGebra. Two students' comments were as follows:

Student 4: "While entering functions, I failed to make the most out of GeoGebra."

Student 5: "My lack of computer skills made it hard for me to use GeoGebra to learn about limits."

The quantitative findings indicate that, according to the data, students were more engaged and enthusiastic during the intervention. As a result of the intervention, students were better able to express their creativity and learn about themselves. We could say that teaching math with GeoGebra-embedded instruction is a good and effective way to do things.

4. Discussion

This study used a Calculus Achievement Test (CAT), a questionnaire, and interviews to find out how well students understood calculus before and after the intervention. It also wanted to find out how they felt about using GeoGebra in calculus and what they thought about it. The questions on the Calculus Achievement Exam, the accompanying questionnaire, and the interview were all set up based on three different levels of accuracy. There were three different types of scales, and they measured things like perceptions towards the benefits of GeoGebra, perceptions towards scaffolding in the classroom, and perceptions towards the learning difficulties of GeoGebra.

The results above are consistent with those of other research that has looked at the impact of a technologically advanced classroom on students' ability to learn (Bedada & Machaba, 2022; Shadaan & Leong, 2013). Since there was a clear improvement, the GeoGebra software could be used as a tool to help teach and learn calculus, especially the study of derivatives of functions. When students used GeoGebra, not only did their test scores go up, but the program was also said to have made the classroom a more interactive place where the ideas of cooperative and collaborative learning were more clear. This is because the best way to learn is through scaffolding and the "zone of proximal development." As a result, after students have developed their understanding (internalization) for externalization, the teacher's role shifts to one of identifying both the environment and the student's abilities, designing, guiding, helping, assisting, facilitating, giving feedback, evaluating, and motivating students to use their learning in the classroom and environment. As such, Vygotskian theory defines learning as the ingesting of culturally given information (Harland, 2003; Marra, 2005; Sanders & Welk, 2005). The educator is ultimately responsible for the classroom's atmosphere; therefore, he or she should know as much as the students do about the advantages of using technology in the classroom. Math organizations that are known for their research should be used to evaluate new teaching tools on a regular basis. For example, for an interview, since I don't have enough time to personally teach every student who doesn't already know GeoGebra. I provide them with a link https://www.geogebra.org/

u/nongharnpitukp to study on their own, as shown in Figures 2 and 3.

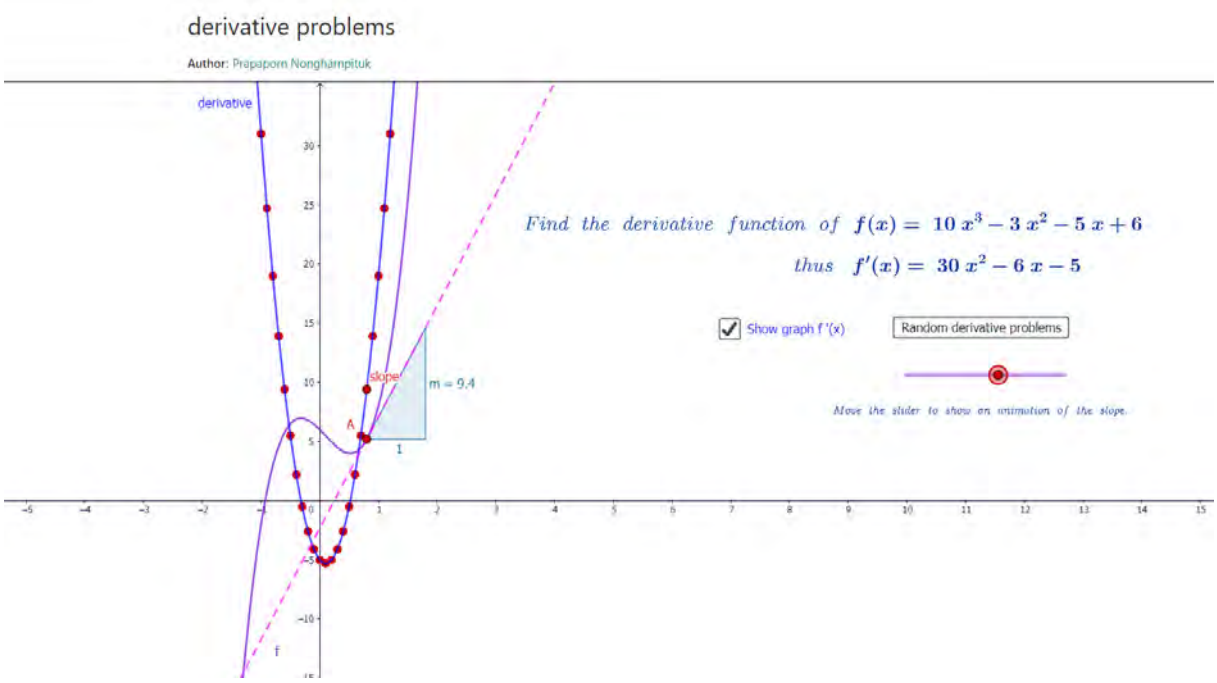

Figure 2. The lesson of GeoGebra in limit and continuous

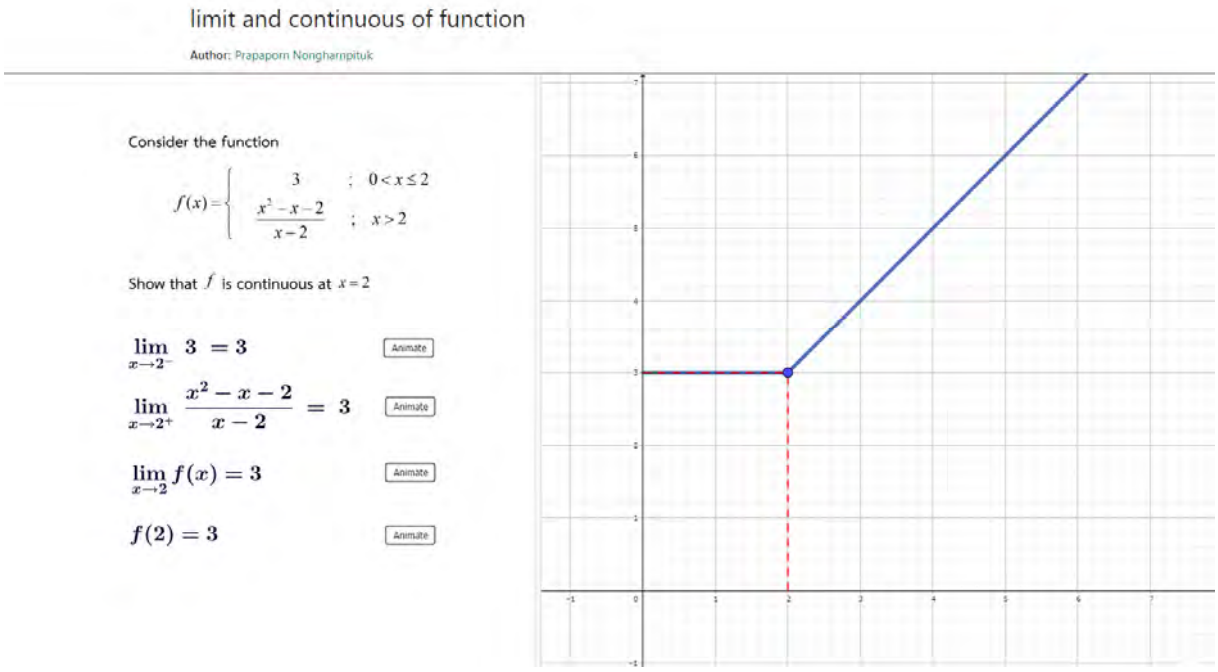

Figure 3. The lesson of GeoGebra in derivatives

The results also suggest that technology may be a terrific source of motivation since students' self-assurance grew when they utilized GeoGebra and learning videos to aid in their education. The students who started out with less aptitude gained the most from this. Learners were able to progress to their own zone of proximal development with the aid of technology (Vygotsky, 1978). Supporting this conclusion is research by Soleh (2020), which found that students' motivation and engagement in learning increased after engaging in computer-based activities that emphasized the development of higher-order thinking skills.

5. Conclusion

The use of technology to improve math skills is still a matter of considerable concern. Some mathematicians still think that using technology in math classes will make it much harder for students to think creatively and improve their skills. Even though some people are concerned that youngsters may lose their capacity to think creatively and solve problems if they spend too much time in front of screens, others say that technology really aids in the cultivation of these skills in today's children. The results I obtained lend credence to the arguments made by both sides. My research shows that students who take whole calculus classes learn with GeoGebra, which can be used in the classroom or at home to help students develop important skills like engagement, self-exploration, visualization, and comprehension. At the end of this piece, I will argue that technology is not making teachers and students less vital. It has become a powerful way to get both students and teachers to try new things and take responsibility for their own learning.

6. Limitations

Implications for mathematics education are discussed, and the study's findings are regarded as invaluable. It does have some restrictions, albeit they could have minimal bearing on the outcomes. To begin with, the years of experience of the professors who actually taught the students varied widely. Second, the researchers were always giving advice to the teacher to make sure that everything went according to plan. Consequently, factors may affect the study's results in varying ways.

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