Hindawi
Education Research International
Volume 2022, Article ID 4400024, 14 pages
https://doi.org/10.1155/2022/4400024

Research Article

The Effect of GeoGebra on Students' Abilities to Study Calculus

Tola Bekene Bedada [1] and M. F. Machaba [2]

[1] *Wachemo University, Department of Mathematics, Hosaena, Ethiopia*
[2] *University of South Africa, Department of Mathematics, Pretoria, South Africa*

Correspondence should be addressed to Tola Bekene Bedada; leencaoro@gmail.com

Received 11 May 2022; Accepted 15 July 2022; Published 11 August 2022

Academic Editor: Enrique Palou

The study aimed to investigate the effect of GeoGebra on students' ability to learn calculus. Calculus can be a challenging subject to teach. Moreover, students have problems, especially in connecting the concepts of calculus with the real world. Concerning gender, the study looked at the impact of utilizing GeoGebra Mathematical software on students' calculus proficiency and ability to utilize GeoGebra software to learn calculus. The study developed a cycle model that posits nine steps to promote the teaching and learning process with the help of GeoGebra to improve the learning process. A quantitative research methodology was employed to achieve the goal of the study. A quasi-experiment with a pretest and posttest design was used in the quantitative part of the study. Students learning calculus were the subjects of the study, which took place at a university in Ethiopia. The quantitative data were analyzed using SPSS version 27. The results show that there is a significant difference between pretest and posttest in students' performance (ability) when using GeoGebra mathematics software, indicating that students performed better after the intervention ($F(1,64) = 10.495$, $p = 0.002 < 0.05$). The treatment benefited both high- and low-ability pupils in their brain-based learning, although students in the experimental group, both female and male, outperformed those in the control group. While the GeoGebra-oriented learning approach to calculus has the potential to improve competency, it is still necessary that it be structured (cycle model) to address a specific deficiency.

1. Background of the Study

It is well known that teaching mathematics by technological means benefits students [1–6]. Inayat and Hamid [7] focused on the advances of technological tools such as Computer Algebra Systems (CAS) and Dynamic Geometry Systems (DGS), and the combination of the two packages in GeoGebra, in terms of their effectiveness in the teaching and learning of mathematics. They argue that such applications promote more effective learning in a student-centered and dynamic environment. They found that in mathematics, innovation in the teaching and learning process was shaped by modern digital technologies offered by web-based applications. A web image has been used to characterize this new way of teaching mathematics in the digital age. Tall [8], as he discussed in the conference proceedings, together with several other researchers, has shown that using computerized technology in mathematics education has many advantages [6, 9, 10].

Curriculum developers, educators, and all students benefit from educational technology's advantages, not least because students are attracted to this visually entertaining and interactive learning mode. Introducing technology in mathematics instruction elevates the motivation level and affect displayed by students in science-related courses of study. Inayat and Hamid [7] and Keong, Horani, and Daniel [11] found that technology-oriented mathematics education enhanced students' understanding of basic concepts. Interactive software can provide an immediate response to students' input, enables interaction and cooperation among students, improves skills, stimulates active participation and assists in integrating theory and models [7].

Some educational software packages for mathematics teaching and learning come at a cost in the market, and many students, teachers, and schools cannot afford to buy them. Subsequently, free open-source software, readily available on the Internet, is in high demand, especially in developing countries. Apart from interactive software applications, courseware and teaching materials are also available. Given the Ethiopian educational setting, this research study focuses on free open-source mathematical software suitable for teaching and learning calculus at the tertiary level. Of the available applications in this category, namely, GeoGebra, Wolfram Alpha, and Desmos, I chose GeoGebra because it is user-friendly, time-saving, simple to use, and easy to manipulate. Any student can download the software onto their electronic device at no cost. This free software is gaining popularity worldwide for both educational and research purposes. In this line, I developed a model known as the cycle model that posits nine steps which are discussed in the theoretical framework of the study.

2. Statement of the Problem

Procedural fluency can be affected by basic instructional routines and by following steps, algorithms, methods, or strategies of calculation and the application of formulae and rules. In the GeoGebra software-based mathematics classroom, the teacher's main task is to guide students' work, as the software enables students to explore and discover mathematics concepts by themselves [12]. This idea is consistent with Vygotsky's classical cognitive constructivist theory. Preiner [12] found that the simple way developers of GeoGebra designed the user interface of the software aligns with the characteristics of cognitive constructivism, particularly its visualizing and explorative capabilities, its contribution to multimedia environments for learning, and the minimization of cognitive load in learning. Multimedia environments offer new ways of learning and teaching compared to traditional environments [12].

Akanmu [13] agrees that technology, well-integrated into mathematics education, enhances students' achievements "irrespective of gender" [13]. In an analysis of 50 articles published from 1997 to 2014, Cai et al. [14] found that male students had more favorable attitudes to technology than females, but these differences were found in small effect sizes. Here we saw conflicting ideas about students' ability and intention to use technology for their learning in terms of gender. So, this study must compromise or provoke one side of the above-stated conflicting ideas.

Students using technology can discover mathematical concepts, test their emerging mathematical understanding, both procedural and conceptual, and experiment and visualise [15]. However, in my country, Ethiopia, from my experience of teaching mathematics, very few students have the technology for learning in the classroom because of their economic background. To this, the study done in Kenya showed that mathematics teachers lag behind regarding adopting new technology, which is directly related to students' experiences of using technology in classroom learning [16]. In contrast, the use of GeoGebra affected learners' learning and positively affected the teacher's beliefs regarding teaching and learning even for those teachers in high-poverty, rural settings where the availability of technological resources is limited [17]. Thus, as most schools are in rural areas, the government is ready to integrate technology into the education system [18].

3. Objectives of the Study

The general objectives of the study were to investigate the effect of GeoGebra on students' ability to learn calculus. The specific objective of the study is to evaluate the effects of GeoGebra on students' abilities in terms of their proficiency in learning calculus with GeoGebra mathematical software in the classroom, concerning the student's gender.

4. Research Questions

The manuscript of the study was written, guided by the following two research questions:

(1) How does the level of differential calculus proficiency in students taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using the traditional methods (control group)?

(2) How does the level of differential calculus proficiency in students from different genders taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using traditional lecturing methods (control group)?

5. Theoretical Model

5.1. A Framework for Mathematical Thinking Development of the Cycle Model. I will demonstrate how the basic mental processes that allowed our forefathers to establish calculus are closely related to the concepts that emerge in our children using the framework of mathematical thinking presented in the study. The mental process will be presented using steps one to nine of the cycle model, developed by Bedada [19] and implemented in the study. This model has to do with how we, as humans, view the changing world by integrating neuronal information from our senses and existing memories into a single phenomenon known as "selective binding" [20]. According to Tall's definition, selective binding happens in milliseconds, or about a forty-fifth of a second. Well-defined objects are manipulated by our brains within the environment (the base of the cycle model, stage 1) to create dynamic software that allows people to interact with calculus concepts to gain insights that are not visible in static images [20]. However, these invisible static images or representations can be measured using tests in mathematics education and expressed in terms of the word proficiencies.

5.1.1. GeoGebra-Oriented Lesson Plan Teaching in Hypothesised Cycle Model. The main aim of this study was to give special consideration to integrating technological, pedagogical, and content knowledge (TPACK) in teaching students' differential calculus with GeoGebra, dynamic multi-purpose mathematics software in a new model, known as a cycle model, developed by Bedada during his PhD studies. According to Bekene [21], a GeoGebra-oriented lesson is a way of implementing some developed steps or designed teaching-learning (lesson plan) in the classroom. "The designed teaching-learning scenario allows students and teachers to focus on specific mathematics learning and teaching and to make sense of the mathematics with foreseeable results for the full range of students in the classroom" [21]. In the implementation stages of the hypothesised cycle model, the teaching material consists of the topics on differential calculus which can be considered a GeoGebra-oriented lesson plan for the experimental group and a traditional oriented lesson plan for control groups. It is accepted that planning helps the teachers to organize and systematise the learning and teaching process. Therefore, planning is important for the teaching of students in a controlled manner in the classroom, and preparing detailed lesson plans is important, especially for beginner teachers who newly experience explicit instruction, modeling, guided practice, and scaffolding. Proficient teachers have been found to start their lesson plans with instructional activities included within the developed lesson plan [22].

The important components of lesson design (lesson plan design tool), sometimes known as task solutions, help the communication between the students and teachers around the contents (differential calculus), technology/GeoGebra, and pedagogy/developed cycle model during the teaching process. Another scholar entertains the definition of lesson plan within the TPACK frameworks by stating that it is the intersection of the integration of pedagogy knowledge (PK), Technology knowledge (TK), and Content Knowledge (CK). The teachers may need to develop meta-knowledge of what presuppositions their local theories, such as a lesson plan, assumed [23].

To summarize, during my study for a PhD, the hypothesised cycle model was used to implement the generated GeoGebra-centered lesson plan employing ideas from TPACK frameworks. The intervention lasts four weeks, and consists of educating students using GeoGebra, and the stages and activities of the cycle model were discussed.

The stages and activities of the developed cycle model are given in Table 1.

5.2. Conceptual Understanding. Conceptual understanding refers to an integrated and functional grasp of mathematical ideas that allow students to reconnect with the designed tasks [24]. Proficiency in representational activities demands conceptual understanding of the mathematical concepts involved (definition of limits, derivatives, etc.), the operations (addition, subtraction, division, and multiplication), and the relations (the combination of concepts such as the relation between natural exponentials and logarithms ($e^{\ln x} = x$)). It also requires strategic competence to formulate and represent that information. Hence, the conceptual tasks require the ability to recall or connect to previous knowledge. In calculus, we know that $\lim_{x\longrightarrow 0}(\sin x/x) = 1$, but if the students are given the task to evaluate $\lim_{x\longrightarrow 0}(\sin x/5x)$, they need to connect the previous knowledge of basic limits to the given rule for the building of students' prior knowledge [25]. Once students have conceptualised the rule, they can simply recall answers. Sumartini and Maryati [25] suggest two measurements of conceptual understanding, implicit and explicit measures. These measurements of conceptual understanding are *implicit* measures and relate to evaluations where one makes definitive choices, ranks quality, and compares numbers; *explicit* measures, on the other hand relate to definitions and explanations. The factors that hinder the recalling or reconnecting of students' to previous knowledge and scaffolding to new knowledge occur in the classroom and these conditions should be identified by the teachers [26]. Factors that are associated with making connections include:

(i) Scaffolding of student activities
(ii) Students' exploration
(iii) Teachers or capable students modeling high-level performance
(iv) Teachers providing activities (questioning, comments, and feedback)
(v) Tasks are developed based on students' prior knowledge
(vi) Teachers make frequent connections in conceptual tasks
(vii) Sufficient time for exploration

5.3. Procedural Understanding. The procedure is the knowledge that shows the order or sequence of actions for comprehensive learning of all the components [27]. Zulnaidi and Zamri elaborated procedural understanding by examples of questions asking students to solve the function equation of $f(x) = x^2 + 1$ to determine the formula of the inverse function $f^{-1}(x)$, and to graph the functions. According to the question, students are required to find the formula of an inverse function. In this case, students need to recall the ways to find inverse functions, such as

(i) Step one: Let $y = f(x) = x^2 + 1$
(ii) Step two: Interchange the variables x with y, that is, $x = y^2 + 1$
(iii) Step three: Solve for y variables, that is, $y = \sqrt{x - 1}$
(iv) Step four: Set $y = f^{-1}(x)$

Here we understand that to arrive at the required formula, students must know these steps or procedures. Thus, in this study, procedural tests require step-by-step activities to arrive at the answers. Procedural understanding is the knowledge of procedures, when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently [24]. In general, even if procedural or conceptual tasks/tests are presented for the students, there are considerations in measuring students' cognitive level that should be kept in mind. Tall [20] states that the embodied (conceptual) world, the symbolic (procedural-perceptual)

Table 1: Stages of cycle model.

Stages	Name of the stages	Activities
1	Environment	Identification of area (environment) (such as laboratory class setting)
2	Individual behavior	Identification of individual areas of interest (teacher professional development and student ability, perception). As the researcher was a teacher, the More Knowledgeable Other (MKO) is present, thus teaching and learning can take place. The pretest was used to identify students' abilities.
3	State objectives	State objectives of teaching a lesson with GeoGebra (by using review literature).
4	Design	Design teaching materials (a lesson plan that is compatible with GeoGebra).
5	Implementation	Implementation of a lesson plan in the classroom (start scaffolding student-student, teacher-student interaction)
6	Feedback	Get feedback from students (responses). This feedback could be in the form of a posttest and interview
7	Evaluation	Evaluation of whether the method had achieved what was intended. Comparison of abilities before and after
8	Internalisation and externalisation	Disseminate and practice the knowledge obtained in the next stages of the cycle model
9	Environment	Practicing the knowledge, they obtained within the environment by becoming MKOs (such as teachers and other experts according to the types of intervention given)

world, and the formal (axiomatic) world are the three mental worlds of mathematics.

5.4. The Use of Technology to Promote the Student's Proficiency (Brain-Based Learning). The concept of student brain enrichment continues to be an important theoretical component of brain-based learning. Within a certain setting, people (students) learn knowledge (both conceptual and procedural knowledge) in a specific pattern. The potential of technology in education to promote constructivist instruction is particularly appealing. Within a given setting in the education system classroom setting, brain-based learning is a way of attaining knowledge from the more knowledgeable others (most of the time a teacher). The role of the teacher is defined in the first phase to cope with the expected brain-based learning. The role of the teacher lies in identifying both the environment and student ability, designing, guiding, helping, facilitating, giving feedback, evaluating, and motivating students to use their learning in the classroom and environment after they have developed their understanding (internalisation) for externalisation. In this regard, Vygotskian theory holds that cognitive development can be described as a process of internalising culturally transmitted knowledge (that can be done by scaffolding) in the cycle model (containing nine steps), in which the exposure to cultural models (cyclical model) stimulates a gradual internal process of knowledge growth (in both conceptual and procedural understanding) in students learning differential calculus with the help of GeoGebra [28, 29].

6. Methodology of the Study

The generated cycle model reflected in Table 1 was utilized to instruct students acquiring calculus in this study.

6.1. Sampling Method. In 2019, Ethiopia had 45 public universities. Of these, Addis Ababa University and Haromaya University are first-generation universities according to the categorisation of Ethiopian universities. Universities are categorized according to the year they were built (from one generation to four generations ago). The researcher chose Wachemo University, a third-generation university, purposefully, specifically for students studying in the Department of Mathematics. The researcher chose this university because the corresponding researcher is a lecturer there, and the problem of the study was raised there. Wachemo University is situated in the Southern Nations, Nationalities, and Peoples (SNNP) regional state of Ethiopia and is 230 km from the capital of the country, Addis Ababa.

One group of undergraduate mathematics students made up the study's participants. The numbers of these students depend on the department's capacity. The researcher used a lottery or a simple random sampling method to select an experimental and control group for the study. This was achieved by identifying the section by coding (code number one indicating students who would be included in the study, code number two indicating those who would be excluded from the study). In total, 30 and 36 freshman students learning mathematics were included in experimental and control groups, respectively. The researcher sampled students by writing the codes 1 or 2 on 60 to 72 pieces of paper. Placing these pieces of paper in a bowl, the researcher asked each student to take a piece of paper from the bowl. This method of including participants in a study is called the fishbowl draw or the lottery method.

6.2. Data Sources and Data Collection Instruments. Wachemo University students learning mathematics were the sources of data for the study, and 36 and 30 students from the control and experimental groups, respectively, were included in the study. The researcher constructed 20 multiple-choice items and four problem topics to solve from differential calculus that were used for the pretest before and the posttest after the intervention [30]. After the pilot study, the researcher narrowed this down to 18 multiple-choice items and two problems, 20 questions in total. The quantitative data were collected using the differential calculus achievement test.

6.3. Issues of Reliability and Validity. One way of verifying the data collection instruments to be used in the main study was the use of a pilot study. Since the pretest covered the subject of differential calculus and was prepared by the researcher, he selected students who were familiar with calculus and would not be participants in the main study. The participants in the pilot study were third-year mathematics students at Wachemo University in the second semester of 2020 who volunteered to participate. They had passed both first- and second-year calculus courses, so they knew about differential calculus. These students would graduate in January 2020 and would no longer be at university when the main study was scheduled to begin, so there would be no possibility of information contamination among students on the campus. Again, the participants in the main study were not on campus when the pilot study was conducted because of COVID-19. During the pilot study, a test and questionnaire for students were administered to 15 participants (and in this manuscript, we only considered a test). This was done to ensure the internal reliability of tests and questionnaires to identify the degree to which the items were cohesive.

To analyse the collected data with SPSS version 27, the researcher coded it for a pilot study. The test contained right or wrong answers (dichotomous data). If students answered correctly, the score was 1; if incorrect, the score was 0. So, *right* = 1 and *wrong* = 0 in the SPSS version 27 database. The pilot study was conducted to check the reliability of the test items that would be used in the main study. Twenty-four differential calculus tests were distributed to 15 students in the pilot study. These tests were divided into 12 procedural and 12 conceptual tests depending on the nature of the constructed items [31, 32]. A differential calculus test or question is in the form of a statement/item. To achieve reliability of the items, the Cronbach alpha value (α), which is the best indicator of internal reliability, was employed for both categories of tests [33]. To this end, item analysis was conducted to determine the item difficulty level of the differential calculus test of achievement (DCAT). Item analysis is a technique that enables the researcher to accept, reject, or adjust items to be included in the main study, which is an important tool to increase the effectiveness of the test [34].

Cronbach's alpha value and interitem correlations were computed to examine the deficit in items ("very simple" and "very difficult") that disturbs another test on the student's achievement, to assess whether the DCAT test score was reliable. The pilot study revealed that the Cronbach alpha value for DCAT was 0.716 after deleting four items, two each from both categories of questions (conceptual and procedural understanding). Three of these items were found to have low interitem correlations with the whole scale, affecting the whole test's reliability. One further item was removed by SPSS, as the item had zero variance. Thus, in the main study, students' achievement and their understanding of calculus were investigated using 20 DCAT items. I divided the tests into a conceptual and procedural understanding depending on the nature of the constructed tests. Procedural questions are questions that can be obtained by following steps, whereas conceptual questions can be obtained by remembering only the formula or logic. Each category of understanding (conceptual and procedural) consisted of ten question items.

6.4. Research Design. The researcher used a quantitative approach to determine students' understanding of learning calculus through technology, in this case, GeoGebra. Quasi-experimental research uses nonrandomised assignments of the study group that are categorized into experimental and control groups [35]. Because of this design choice, the study included 36 and 30 students in the control and experimental groups, respectively. After implementing certain interventions using the cycle model's stages 1 through 7, the researcher administered a differential calculus accomplishment test to the study participants. The research strategy and techniques are summarized in the diagram below (see Table2).

7. Data Analysis and Findings

7.1. Study Context (Environment). This section provides information on the area (environment) where the study took place, in this case, a laboratory classroom at the university. Vygotsky's ideas are reflected in the community of practice thinking that addresses the need for continuous professional development and lifelong learning in the environment [36]. The environment can be viewed from the biological perspective (phylogenesis and fatal development) and the psychological perspective. The "environment" or "real world" can be articulated and described only in terms of viable intangible structures by observers [37]. Within the school environment, teaching and learning activities occur, using a variety of reinforcements, such as praise, rewards, and grades. To initiate the articulation of objects in the environment, indicated on the left side of Figure1, I first identified the environment.

The computer laboratory in the Department of Mathematics at Wachemo University was not well organized and unsuitable for the intervention. Thus, I searched for and found a suitable laboratory before starting the main study. Figure 2 provides images of this laboratory at the university. The researcher felt it was important to determine the study area before commencing with the intended intervention, which is the basis of the newly developed cycle model.

7.1.1. Analysis of Group Differences in Pretest of Differential Calculus Achievement: Stage 2 of Cycle Model. Differential calculus is an important part of mathematics because it serves as a basis for more advanced courses in mathematics and engineering at secondary and higher education levels. It has many applications in real life. In this section, students' scores on differential calculus achievement tests (DCAT) were obtained. The test comprised 20 items,

Table 2: Research design and procedure.

Experimental group 30 students	Pretest before intervention	High achievers Low achievers	Treatment (teaching using GeoGebra following all stages of the cycle model)	Posttest after intervention
Control group 36 students	Pretest before intervention		Conventional teaching (lecturer)	Posttest after intervention

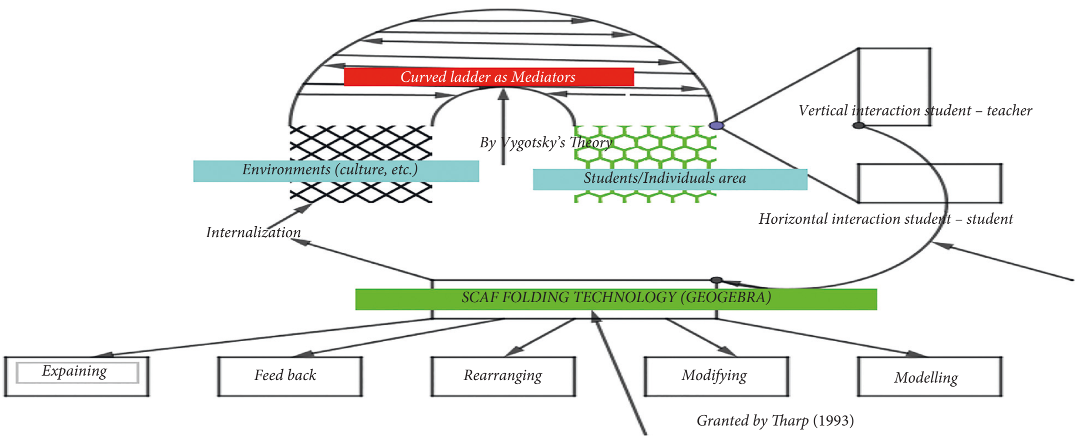

Figure 1: The base of the cycle model adapted from Bedada [19].

Figure 2: Wachemo university laboratory.

Table 3: Overall descriptive statistics of the two groups' proficiency in differential calculus before the intervention.

Groups	Differential calculus achievement (before intervention)			
	N	Mean	SD	Std. Error
Experimental	30	27.000	9.965	1.819
Control	36	26.667	10.823	1.804
Total	66	26.8182	10.364	1.276

ten items on procedural knowledge and ten on conceptual knowledge, developed by the researcher and administered at the beginning of the study. This pretest was used to investigate the initial differences (if any) between the two groups in the study in terms of their performance in a differential calculus achievement test (DCAT) to address the two research questions in the study: (1) How does the level of differential calculus proficiency in students taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using the traditional methods (control group)? (2) How does the level of differential calculus proficiency in students from different genders taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using traditional lecturing methods (control group)? Scores obtained from the pretest were analyzed by applying an independent samples T-test, which compares the means of the two groups as shown in Table3. To ensure the use of the T-test [38], I computed the normality of pretest recorded data, as shown in Table 4. This showed that the pretest was normally distributed in both groups in the study, as the significance level in both tests was greater than 0.05.

Table 3 shows a mean difference of 0.333 between Group1 ($M = 27.000$) and Group 2 ($M = 26.667$). This indicates that the two groups were very similar as the difference was not significant at 0.05 ($p = 0.898 > 0.05$) (see Table 5). Students in the two groups had similar academic backgrounds, with each group consisting of both high and low achievers.

The uniformity in the results of the two groups was a good starting point for me to deduce whether the treatment had an effect after the intervention had occurred. Hence, if the experimental group scored higher than the control group on the posttest, the researcher could assume that the differences had occurred because of the treatment in the study,

Table 4: Test normality of pretest.

	Group	Kolmogorov–Smirnov			Shapiro–Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
Pre-test	Experimental	0.119	30	0.200	0.946	30	0.133
	Control	0.145	36	0.055	0.957	36	0.172

by controlling other confounding variables. In this regard, I tried to control all the possible confounding variables such as time allocation for a lesson, the effect of the teacher (this was controlled by using the researcher as the teacher for both groups), and topics covered (this was controlled by focusing on the harmonized Ethiopian curriculum). The one-way ANOVA is summarized in Table 5. This provided further analysis of the two groups and within the groups (experimental and control).

The results in Table 5 show that there was a statistically nonsignificant difference in pretest differential calculus achievement (F $(1, 64) = 0.017$, $p = 0.898 > 0.05$). The dependent variable in this study was students' proficiency in differential calculus, which may have been influenced by the other variables (groups). Hence, the study investigated the conceptual and procedural understanding of both groups before the treatment as a starting point, as tabulated in Table 6.

Table 6 shows that the mean scores of experimental group 1 on both preprocedural and preconceptual understanding of DCAT were $M = 10.667$ and $M = 16.333$, respectively, with a mean difference of 5.667. This indicates that students in this group had a better conceptual understanding than procedural understanding before the intervention. The mean for control group 2 was $M = 12.778$ and $M = 13.889$ for preconceptual and preprocedural understanding, respectively, with a mean difference of 1.111, indicating that some students in the control group had the same level of procedural and conceptual understanding of differential calculus before the intervention. Table 7 shows that both male and female students had a better conceptual understanding of differential calculus than the procedural understanding before the intervention. An ANOVA was calculated to determine whether there was any significant difference between the mean scores of the groups in terms of two types of knowledge. The one-way ANOVA is summarized in Table 8.

Table 8 indicates that there were statistically nonsignificant differences in both conceptual and procedural understanding of differential calculus before the treatment, with the values F $(1, 64) = 2.017$, $p = 0.160 > 0.05$ and F $(1, 64) = 2.113$, $p = 0.151 > 0.05$, respectively. Next, I was interested in investigating students' abilities within each group regarding the two types of knowledge involved in understanding differential calculus.

7.1.2. Analysis of Students' Ability within Groups. When dividing students into two groups within groups, the researcher considered their pretest scores to investigate the GeoGebra treatment effects on diverse achievers. These were divided into two groups, higher and lower achievers, using the pretest score median of each group. Next, the researcher categorized students into nested groups (below the median of 27.5 [low-ability]), 16 in total, and above-median of 27.5 as high ability (14 in total) for the experimental group. Of these students, only two female students were categorized as high achievers, and none were higher achievers in procedural or conceptual

Table 5: Overall one-way analysis of variance–summary table comparing groups' achievement in differential calculus before treatment.

	Sum of squares	Df	Mean square	F	Sig.
Differential calculus achievement test (before intervention)					
Between groups	1.818	1	1.818	0.017	0.898
Within groups	6980.000	64	109.063		
Total	6981.818	65			

Table 6: Overall descriptive statistics of achievement in differential calculus of the two groups (conceptual and procedural understanding) before treatment.

Groups		Student's proficiency within groups: Pretest conceptual	Pretest procedural
Experimental	Mean	16.333	10.667
	N	30	30
	Std. deviation	6.557	5.833
Control	Mean	13.889	12.778
	N	36	36
	Std. deviation	7.281	5.909
Total	Mean	15.000	11.818
	N	66	66
	Std. deviation	7.016	5.925

Table 7: Students' proficiency by gender before the intervention.

Gender		Students' proficiency by *gender: Pretest procedural	Pretest conceptual
Female	Mean	12.917	12.083
	N	12	12
	Std. deviation	7.217	6.895
Male	Mean	15.463	11.759
	N	54	54
	Std. deviation	6.955	5.759
Total	Mean	15.000	11.818
	N	66	66
	Std. deviation	7.016	5.925

Table 8: Overall one-way analysis of variance summary table comparing groups' proficiency in differential calculus before treatment.

Understanding		Sum of squares	Df	Mean square	F	Sig.
Pretest conceptual	Between groups	97.778	1	97.778	2.017	0.160
	Within groups	3102.222	64	48.472		
	Total	3200.000	65			
Pretest procedural	Between groups	72.929	1	72.929	2.113	0.151
	Within groups	2208.889	64	34.514		
	Total	2281.818	65			

proficiency. However, the sum of the two (procedural proficiency and conceptual proficiency) or one proceed to the other (procedural proficiency proceed to conceptual proficiency and vice versa) and resulted in their categorisation as high achievers [39–41]. Twelve male students were higher achievers, but only one male student was a high achiever in procedural proficiency; the others were becoming high achievers, as reflected in the sum of the scores on the two types of proficiency before the intervention. Of the 36 students in the control group, 17 were included in the high achiever category as their scores were higher than the median of 25; 19 students were low achievers as their scores fell below the median of 25. Of these students, only three female students were high achievers, and none were high achievers in procedural or conceptual proficiency; the sum of their scores on the two types of proficiency allowed them to be categorized as high achievers (see Table 9). Fourteen male students and three female students were high achievers in the procedural understanding of calculus; 12 male students and two female students were high achievers in procedural understanding.

7.1.3. The Difference between Students' Proficiency and Students' Ability. Students' ability was the same on admission for both groups before the intervention on differential calculus. Although students' ability before being introduced to differential calculus was very similar, there were some differences in their proficiency.

Table 10 shows whether, in terms of their ability, experimental and control group students' procedural and conceptual understanding of differential calculus differed before the treatment. The table shows that there were statistically significant differences in both conceptual and procedural understanding of differential calculus by student ability before the treatment, with the values $F(1, 64) = 42.6$, $p < 0.5$, and $F(1, 64) = 33.6$, $p < 0.5$. To determine the extent of the difference between the two groups in terms of the two proficiencies, I used effect size (ES). For the ANOVA test, the effect size can be calculated by

$$\text{Eta squared} = \frac{\text{Sum of the squares between groups}}{\text{Total sum of squared}}. \quad (1)$$

According to the formula, the effect size of the preconceptual understanding of the experimental and the control group was computed as [42]

$$\begin{aligned}\text{Eta squared} &= \frac{\text{Sum of the squares between groups}}{\text{Total sum of squared}}\\ &= \frac{1278.940}{3200.000}\\ &= 0.4.\end{aligned} \quad (2)$$

Eta squared = 0.4 indicates a small effect size; this, in turn, implies a small difference between the two groups (experiment and control) in terms of pretest conceptual understanding in terms of achievement [42].

The effect size of the pretest procedural understanding of the experimental and control group was computed as

$$\begin{aligned}\text{Eta squared} &= \frac{\text{Sum of the squares between groups}}{\text{Total sum of squared}}\\ &= \frac{785.505}{2281.818}\\ &= 0.34.\end{aligned} \quad (3)$$

This indicates that pretest procedural understanding of students had a small effect size, implying that there were small statistically significant differences in the two groups in pretest procedural in differential calculus.

7.2. Analysis of Group Differences in Posttest of Differential Calculus: Stage 7 of Cycle Model. After the intervention had been completed, the posttest was administered to both the experimental and the control group, aligning with the evaluation stages of the cycle model. The research questions of the study: (1) How does the level of differential calculus proficiency in students taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using the traditional methods (control group)? (2) How does the level of differential calculus proficiency in students from different genders taught using GeoGebra with the help of a newly developed instructional technology (experimental group) compare to those taught using traditional lecturing methods (control group)? A posttest was administered to both groups to address these questions. The recorded posttest scores achieved after the intervention were analyzed and are reflected in Table 11.

Table 11 shows that the mean score of the experimental Group 1 in the posttest was $M = 41.167$ and that of the control Group 2 was $M = 31.111$; the mean difference

Table 9: Descriptive statistics of students' proficiency by gender before treatment.

Proficiency	Student ability	Genders	Groups	Mean	SD	N
Preconceptual	Low ability	Female	Experimental	6.7	2.9	3
			Control	10.0	4.1	4
			Total	8.6	3.8	7
		Male	Experimental	13.5	4.7	13
			Control	9.7	5.8	15
			Total	11.4	5.6	28
		Total	Experimental	12.2	5.2	16
			Control	9.7	5.4	19
			Total	10.9	5.4	35
	High ability	Female	Experimental	17.5	3.5	2
			Control	20.0	8.7	3
			Total	19.0	6.5	5
		Male	Experimental	21.7	4.4	12
			Control	18.2	6.1	14
			Total	19.8	5.6	26
		Total	Experimental	21.1	4.5	14
			Control	18.5	6.3	17
			Total	19.7	5.6	31
	Total	Female	Experimental	11.0	6.5	5
			Control	14.3	7.9	7
			Total	12.9	7.2	12
		Male	Experimental	17.4	6.1	25
			Control	13.8	7.3	29
			Total	15.5	6.95	54
		Total	Experimental	16.3	6.6	30
			Control	13.9	7.3	36
			Total	15.0	7.0	66
Preprocedural	Low ability	Female	Experimental	5.0	5.0	3
			Control	11.3	4.8	4
			Total	8.6	5.6	7
		Male	Experimental	7.7	4.8	13
			Control	9.3	4.95	15
			Total	8.6	4.9	28
		Total	Experimental	7.2	4.8	16
			Control	9.7	4.9	19
			Total	8.6	4.9	35
	High ability	Female	Experimental	15.0	7.1	2
			Control	18.3	5.8	3
			Total	17.0	5.7	5
		Male	Experimental	14.6	3.96	12
			Control	15.7	5.1	14
			Total	15.2	4.6	26
		Total	Experimental	14.6	4.1	14
			Control	16.2	5.2	17
			Total	15.5	4.7	31
	Total	Female	Experimental	9.0	7.4	5
			Control	14.3	6.1	7
			Total	12.1	6.9	12
		Male	Experimental	11.0	5.6	25
			Control	12.4	5.9	29
			Total	11.8	5.8	54
		Total	Experimental	10.7	5.8	30
			Control	12.778	5.9	36
			Total	11.8	5.9	66

N.B. pre-conc = pretest conceptual on pretest, pre-pro = pretest procedural on pretest.

between the two groups was *10.056,* indicating that the scores of the two groups were significantly different at 0.05 ($p = 0.002 < 0.05$) after the intervention (see Table 12). To determine which gender was responsible for the difference, I computed the overall descriptive statistics for the analysis of gender, as tabulated in Table 12.

Table 13 shows that both male and female students benefited from the intervention. Next, the researcher

Table 10: Overall one-way analysis of variance summary: students' proficiency in differential calculus compared to their ability before treatment.

Variables		Sum of squares	df	Mean square	F	Sig.
Pretest conceptual	Between groups	1278.940	1	1278.940	42.608	0.000
	Within groups	1921.060	64	30.017		
	Total	3200.000	65			
Pretest procedural	Between groups	785.505	1	785.505	33.597	0.000
	Within groups	1496.313	64	23.380		
	Total	2281.818	65			

Table 11: Overall descriptive statistics for two groups on differential calculus achievement after the treatment.

Comparison of pretest scores and posttest scores of groups			
Interventions		Pretest scores	Posttest scores
Experimental ($N = 30$)	Mean	27.000	41.167
	Std. deviation	9.965	13.814
Control ($N = 36$)	Mean	26.667	31.111
	Std. deviation	10.823	11.409
Total	Mean	26.818	35.682
	Std. deviation	10.364	13.442

Table 12: Overall one-way analysis of variance summary table comparing groups on differential calculus achievement after the treatment.

Comparing groups on differential calculus understanding						
Statistic		Sum of squares	Df	Mean square	F	Sig.
Pretest scores	Between groups	1.818	1	1.818	0.017	0.898
	Within groups	6980.000	64	109.063		
	Total	6981.818	65			
Posttest scores	Between groups	1654.596	1	1654.596	10.495	0.002
	Within groups	10089.722	64	157.652		
	Total	11744.318	65			

Table 13: Pretest scores and posttest scores by gender.

Pretest scores and posttest scores by gender			
Interventions		Pretest scores	Posttest scores
Female	Mean	25.0000	31.2500
	Std. deviation	11.07823	9.32372
Male	Mean	27.2222	36.6667
	Std. deviation	10.26382	14.07527
Total	Mean	26.8182	35.6818
	Std. deviation	10.36400	13.44179

investigated which students' proficiency was causing the differences. For this, an ANOVA was calculated to investigate the difference in students' achievement in both types of knowledge in the posttest of differential calculus. These results are tabulated in Table 12.

The results in Table 12 show that there was a statistically significant difference in students' achievement in differential calculus post-intervention ($F\ (1,\ 64) = 10.495$, $p = 0.002 < 0.05$). There was a statistically significant difference in students' achievement in the pretest of differential calculus ($F\ (1,\ 64) = 0.17$, $p = 0.898 > 0.05$) with effect size (ES) $d = 1$. Thus, it could be argued that the improvement resulted from the treatment. Students' ability results on the test of conceptual and procedural understanding of differential calculus were analyzed and are depicted in Figure 3.

Figure 3 shows that both high-ability and low-ability students benefited from the treatment, but students in the experimental group scored higher than the control group.

Figure 4 indicates that both female and male students in the experimental group scored higher than students in the control group. These findings align with a study that found that female students learning a given course with the help of GeoGebra achieved scores superior to those of a control group taught by traditional methods. They also showed greater survival of learning impact, defined by learning output retained in memory as indicated in scores on a posttest [19, 43].

8. Discussion and Conclusion: Stages 7, 8, and 9 of the Cycle Model

Learning calculus is a difficult skill to be taught. Students have problems, especially in connecting calculus concepts with the real world. They are reluctant to conceptualize their

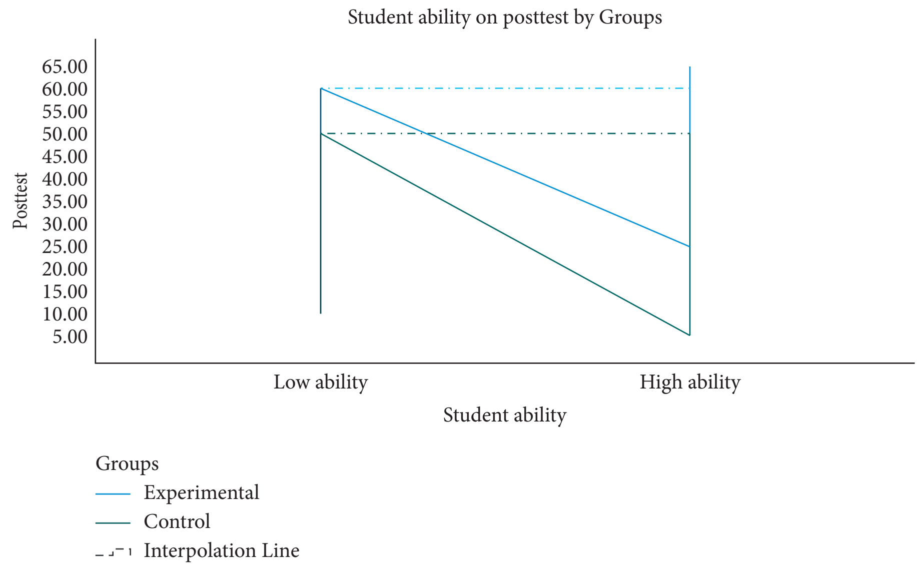

Figure 3: Student ability in experimental and control groups.

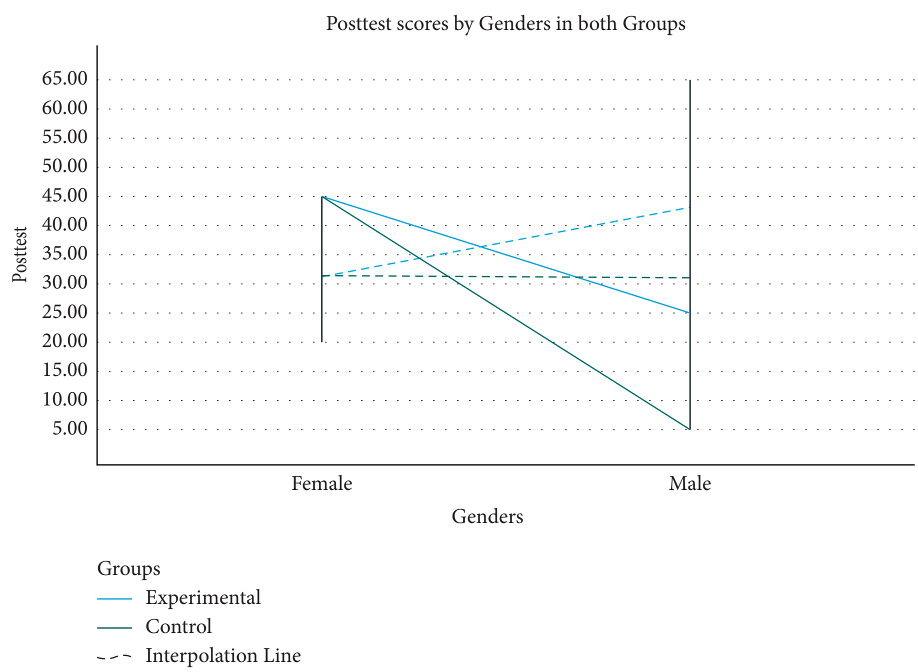

Figure 4: Gender difference in scores on posttest in both groups.

ideas and make procedural errors and faults. The study's findings indicate that using GeoGebra software in instruction will promote decent learning outcomes in mathematics, especially in the topic of differential calculus. There is a statistically significant difference in students' achievement in differential calculus after the interventions using GeoGebra mathematics software, and the results indicate that the students using GeoGebra mathematics software did better after the interventions ($F\ (1, 64) = 10.495$, $p = 0.002 < 0.05$). The treatment benefited both high- and low-ability pupils, although the students in the experimental group outperformed those in the control group. Both female and male students in the experimental group outperformed those in the control group. These findings align with a study that found that female students learning a given course with the help of GeoGebra achieved scores superior to those of a control group taught by traditional methods. They also showed greater survival of learning impact, defined by learning output retained in memory as indicated in scores on a posttest.

In the GeoGebra-oriented classroom, the students benefited more in terms of procedural understanding than conceptual understanding, while in the control group, the reverse result was reported. The improvement in achievement/scores of students can be attributed to the vast learning opportunity they gained from the GeoGebra classroom-oriented approach. One of the advantages came from the interactivity and supplementary materials. During the intervention, students found scaffolding in the explanation of the concepts, modeling, and rearranging of fixed differential calculus questions on topics discussed in the classroom important and attractive. Using computed effect size (ES), the groups showed small to moderate differences in terms of preintervention conceptual, preintervention procedural, and postintervention conceptual understanding of differential calculus, indicating a relationship between the two [44]. In addition, when observing both types of knowledge in each group, the findings revealed that in the experimental group, students' differential calculus proficiency (conceptual: median = 15 to median = 17.5, and procedural: median = 10 to median = 20) had increased as had their overall scores [45]. In the experimental group, procedural understanding of differential calculus had increased more than conceptual understanding as GeoGebra enables students' visualisation. The transformation of procedural to conceptual understanding requires a gradual integral reconstruction of students' perceptions towards the use of GeoGebra, even though the students expressed positive perceptions towards the use of GeoGebra during the study [46]. Therefore, the findings indicated that instruction with GeoGebra positively affected students' scores in both conceptual and procedural understanding of differential calculus, contrary to the conclusions from Ocal [47] who reported that GeoGebra did not affect procedural understanding. However, procedural understanding can be considered the mediator between conceptual understanding and student achievement [27].

9. Limitation of the Study

This study was not conducted without some limitations. One possible limitation was that the study included self-reported views. A second issue that might have affected this study's data quality was the low computer ability level of students in the experimental group; they might have failed to benefit fully from the potential of the approach, especially during the externalisation stage of the cycle model.

In addition, the smooth implementation of the intervention was affected by electrical outages and the absence of a well-organized mathematics laboratory. This situation affected the study, although the researcher did his best to continue the experiment by changing his schedule. The schedule changes were managed by arranging classes at the times when the university generator was functioning as a power supply for some purpose, such as powering the cafeteria or library. The manuscript only reports students' ability to learn calculus with the help of GeoGebra using the newly developed cycle model.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure

All views and results of this study are only that of the authors. This paper is engaged from Tola Bekene Bedada's thesis with the title "The use and effect of GeoGebra software in calculus at Wachemo University Ethiopia: An investigation."

Conflicts of Interest

The authors declare no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

Authors' Contributions

Tola Bekene Bedada conceived and designed the experiments, performed the experiments, analyzed and interpreted the data, and wrote the paper. Prof. M. F. Machaba supervised the corresponding researcher and designed the experiment.

Acknowledgments

The authors are grateful to all the enumerators (The Mathematics Department of Wachemo University and the University of South Africa) and the study participants who participated until the completion of this study. The corresponding author also wishes to thank his PhD thesis supervisor Prof. M. F. Machaba, for his advice and support.

References

[1] J. A. Dossey, S. S. McCrone, and K. T. Halvorsen, "Mathematics education in the USA 2016," in *Proceedings of the 13th International Congress on Mathematical Education (ICME-13)*, Hamburg, Germany, 2016.
[2] R. Heinich, M. Molenda, J. D. Russell, and S. E. Smaldino, *Instructional Media and Technologies for Learning*, University of California, Oakland, CA, USA, 7th edition, 2002.
[3] Z. Lavicza, T. Prodromou, K. Fenyvesi et al., "Integrating STEM-related technologies into mathematics education at a large scale," *International Journal for Technology in Mathematics Education*, vol. 27, no. 1, pp. 1–11, 2019.
[4] NCTM, *Principles and Standards for School Mathematics*, J. Carpenter and S. Gorg, Eds., National Council of Teachers of Mathematics, Reston, VA, USA, 2000.
[5] R. Pierce and L. Ball, "Perceptions that may affect teachers' intention to use technology in secondary mathematics classes," *Educational Studies in Mathematics*, vol. 71, no. 3, pp. 299–317, 2009.
[6] A. ten Brummelhuis and E. Kuiper, "Driving forces for ICT learning," in *International Handbook of Information Technology in Primary and Secondary Education*, J. Voogt and G. Knezek, Eds., Springer, Berlin, Germany, pp. 117–128, 2008.

[7] M. F. Inayat and S. N. Hamid, “Integrating new technologies and tools in teaching and learning of mathematics: an overview,” *Journal of Computer and Mathematical Sciences*, vol. 7, no. 3, pp. 122–129, 2016, https://www.compmath-journal.org.
[8] D. Tall, “The evolution of calculus: a personal experience 1956–2019,” *Conference on Calculus in Upper Secondary and Beginning University Mathematics*, vol. 1–17, 2019.
[9] A. Ayub, T. Sembok, and W. S. Luan, “Teaching and learning calculus using computer,” in *Electronic Proceedings of the 13th Asian Technology Conference in Mathematics*, pp. 1–10, Bangkok, Thailand, 2008.
[10] A. F. M. Ayub, M. Z. Mokhtar, W. S. Luan, and R. A. Tarmizi, “A comparison of two different technologies tools in tutoring Calculus,” *Procedia Social and Behavioral Sciences*, vol. 2, no. 2, pp. 481–486, 2010.
[11] C. C. Keong, S. Horani, and J. Daniel, “A study on the use of ICT in mathematics teaching,” *Malaysian Online Journal of Instructional Technology (MOJIT)*, vol. 2, no. 3, pp. 43–51, 2005.
[12] J. Preiner, *Dynamic Mathematics Software to Mathematics Teachers: The Case of GeoGebra*, University of Salzburg, Salzburg, Austria, 2008.
[13] I. A. Akanmu, *Effect of GeoGebra Package on Learning Outcomes of Mathematics (Secondary School) Students in Ogbomoso North Local Government Area of Oyo State*, pp. 83–94, 2015.
[14] Z. Cai, X. Fan, and J. Du, “Gender and attitudes toward technology use: a meta-analysis,” *Computers & Education*, vol. 105, pp. 1–13, 2008.
[15] J. Olive, K. Makar, V. Hoyos, L. K. Kor, O. Kosheleva,, and R. Sträβer,, “Mathematical knowledge and practices resulting from access to digital technologies,” in *in Mathematics Education and Technology-Rethinking the Terrain: The 17th ICMI Study*, C. Hoyles and J.-B. Lagrange, Eds., pp. 133–177, Springer, Berlin, Germany, 2010.
[16] I. M. Mwingirwa and M. K. Marguerite, “Status of teachers’ technology uptake and use of geogebra in teaching secondary school mathematics in Kenya,” *International Journal of Research in Education and Science*, vol. 2, no. 2, pp. 286–294, 2016.
[17] M. Mthethwa, Department of Mathematics Science and Technology Education University of Zululand KwaDlangezwa South Africa, M. J. Bossé, and D. Williams, “Geogebra for learning and teaching: a parallel investigation,” *South African Journal of Education*, vol. 40, no. 2, pp. 1–12, 2020.
[18] T. Teferra, A. Asgedom, J. Oumer, T. W/hanna, A. Dalelo, and B. Assefa, “Ethiopian education development roadmap (2018-30) (Issue July),” 2018, https://planipolis.iiep.unesco.org/sites/planipolis/files/ressources/ethiopia_education_development_roadmap_2018-2030.pdf.
[19] T. Bekene Bedada and F. Machaba, “The effect of geogebra on STEM students learning trigonometric functions,” *Cogent Education*, vol. 9, no. 1, pp. 1–18, 2022.
[20] D. O. Tall, “Dynamic mathematics and the blending of knowledge structures in the calculus,” *ZDM*, vol. 41, no. 4, pp. 481–492, 2009.
[21] T. Bekene, “Implementation of geogebra a dynamic mathematical software for teaching and learning of calculus in Ethiopia,” *International Journal of Scientific Engineering and Research*, vol. 11, no. 9, pp. 838–860, 2020.
[22] F. Z. Allahverdi and L. Gelzheiser, “Comparison of a more effective and a typical teachers’ lesson plan detail,” *Sakarya University Journal of Education*, vol. 11, no. 1, pp. 83–100, 2021.
[23] K. Krauskopf, C. Zahn, and F. W. Hesse, “Cognitive processes underlying TPCK: mental models, cognitive transformation, and meta-conceptual awareness,” in *Technological Pedagogical Content Knowledge: Exploring, Developing, and Assessing TPCK*, C. Angeli and N. Valanides, Eds., pp. 63–88, Springer, Berlin, Germany, 2015.
[24] J. Kilpatrick, J. Swafford, and B. Findell, *Adding it up: Helping Children Learn Mathematics*, 2001.
[25] T. S. Sumartini and I. Maryati, “GeoGebra application for quadratic functions,” *Journal of Physics: Conference Series*, vol. 1869, no. 1, Article ID 012138, 2021.
[26] C. Stein and M. S. Smith, “Mathematical tasks as a framework for reflection: from research to practice,” *International Paramedic Practice*, vol. 1, no. 1, pp. 17–21, 2011.
[27] H. Zulnaidi and S. N. A. Syed Zamri, “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*, vol. 13, no. 6, pp. 2155–2180, 2017.
[28] P. Nezhnov, E. Kardanova, M. Vasilyeva, and L. Ludlow, “Operationalizing levels of academic mastery based on Vygotsky’s theory: the study of mathematical knowledge,” *Educational and Psychological Measurement*, vol. 75, no. 2, pp. 235–259, 2014.
[29] L. Vygotsky, “Interaction between learning and developing,” in *Readings on the Development of Children*, Gauvain and Cole, Eds., pp. 34–40, Scientific American Books, 1978.
[30] J. Mcmillan and S. Schumacher, *Research in Education Evidence-Based Inquiry*, Pearson Education Limited, London, UK, 7th edition, 2014.
[31] C. Bergsten, J. Engelbrecht, and O. Kågesten, “Conceptual and procedural approaches to mathematics in the engineering curriculum-comparing views of junior and senior engineering students in two countries,” *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 13, no. 3, pp. 533–553, 2016.
[32] D. L. Jones and J. E. Tarr, “An examination of the levels of cogitive demand required by probability tasks in middle grades mathematics textbooks,” *Statistics Education Research Journal*, vol. 6, no. 2, pp. 4–27, 2007.
[33] J. Pallant, *Survival Manual:A Step by Step Guide to Data Analysis Using SPSS for Windows*, Ligare Book Printer, Riverwood, Australia, 3rd edition, 2007.
[34] L. R. Sharma, “Analysis of difficulty index, discrimination index and distractor efficiency of multiple choice questions of speech sounds of English,” *International Research Journal of MMC*, vol. 2, no. 1, pp. 15–28, 2021.
[35] W. R. Shadish and J. K. Luellen, “Quasi-experimental designs,” in *Encyclopedia of Statistics in Behavioral Science*, B. S. Everitt and D. C. Howell, Eds., vol. 3pp. 1641–1644, 2005.
[36] A. Heinze and C. Procter, “Online communication and information technology education,” *Journal of Information Technology Education: Research*, vol. 5, pp. 235–249, 2006.
[37] E. von. Glasersfeld, *Radical Constructivism: A Way of Knowing and Learning*, Falmer Press, Bristol, PA, USA, 1996.
[38] A. Elliott and W. Woodward, “Statistical analysis quick reference guidebook,” in *Statistical Analysis Quick Reference Guidebook*SAGE Publications, Thousand Oaks, CA, USA, 2007.

[39] B. Finn and J. Metcalfe, "Scaffolding feedback to maximize long-term error correction," in *Memory & Cognition*vol. 38, no. 7, pp. 951–961, 2010.

[40] National Research Council, A. I. Up, and Helping children learn mathematics, *in Mathematics Learning Study Committee*, J. Kilpatrick, J. Swafford, and B. Findell, Eds., National Academy Press, Washington, DC, USA, 2001.

[41] B. Rittle-Johnson and M. W. Alibali, "Conceptual and procedural knowledge of mathematics: Does one lead to the other?" *Journal of Educational Psychology*, vol. 91, no. 1, p. 175, 2021.

[42] L. Cohen, L. Manion, and A. K. Morrison, *Research Methods in Education*, 8th edition, 2018.

[43] M. S. Alabdulaziz, S. M. Aldossary, S. A. Alyahya, and H. M. Althubiti, "The effectiveness of the geogebra programme in the development of academic achievement and survival of the learning impact of the mathematics among secondary stage students," *Education and Information Technologies*, vol. 26, no. 3, pp. 2685–2713, 2021.

[44] M. W. Ellis and R. Q. Berry, "The paradigm shift in mathematics education: explanations and implications of reforming concepts of teaching and learning," *Mathematics Educator*, vol. 15, no. 1, pp. 7–17, 2005.

[45] L. Diković, "Applications geogebra into teaching some topics of mathematics at the college level," *Computer Science and Information Systems*, vol. 6, no. 2, pp. 191–203, 2009.

[46] I. Attorps, K. Björk, and M. Radic, "The use of mathematics software in university mathematics teaching," in *Proceedings of the 7th Congress of the European Society for Research in Mathematics Education*, pp. 2188–2197, 2011.

[47] M. F. Ocal, "The effect of geogebra on students' conceptual and procedural knowledge: the case of applications of derivative," *Higher Education Studies*, vol. 7, no. 2, pp. 67–78, 2017.