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GeoGebra Training and University Mathematics Teachers' Teaching Practices

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ABSTRACT

This paper is aimed at assessing the effect of GeoGebra software training intervention on the University Mathematics Teachers' (UMTs') integration of the software GeoGebra into their mathematics teaching practices. Using a mixed-methods approach and a non-equivalent group quasi-experimental design, the study initially surveyed 96 UMTs across three universities to evaluate their existing perceptions, beliefs, skills, and level of GeoGebra usage in the classroom. To this end, the baseline results from a one-way ANOVA showed significant mean difference between the UMTs' extent of skills in using GeoGebra with and ability to utilize the software algebraic and geometric mathematical concepts ( ) at the three universities. However, following the training intervention, the computed mean of the UMTs' extent of perceptions, beliefs, skills, and the software GeoGebra usage increased significantly across all groups, eliminating the previous disparities between universities. Furthermore, a paired-samples t-test confirmed that the training intervention significantly improved all measured values of the UMTs' extents of perceptions on the software GeoGebra, beliefs toward using the software, skills to use it, and the software GeoGebra usage in their mathematics teaching practices ($p < .001$) with Cohen's $d = .51$ to 1.86. The qualitative findings complement these results, revealing that UMTs view GeoGebra as an essential tool in their mathematics teaching practices. Participants noted that the software creates a more conducive environment for teaching mathematics, simplifies and saves time when solving a mathematical problem, and enhances efficiency in understanding complex mathematical concepts.

Keywords: GeoGebra, Mathematics Teaching Practices, University Mathematics Teachers, Training, Perceptions, Beliefs, Skills.

1. INTRODUCTION

Technological integration has become a cornerstone of the 21st-century quality education. But, the quality of education still exists in low-tech contexts, though the technology enhances it. Driven by rapid technological advancement, the Ministry of Education (MoE) of Ethiopia

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initiated the Educational Road Map (2019–2030) (Teferra et al., 2018). To this end, this road map integrates technology such as Python, GeoGebra, Math Lab, Latex and Mathematica as one course named Mathematical Software for the Mathematics Department students. Countries also transitioned their teaching strategies to online education in response to the COVID-19 pandemic, though its effectiveness varied significantly across nations (Koumiti et al., 2024). Thus, with the development of technology and the demand for highly skilled professionals, integrating technology in HEIs has become increasingly vital. The role of technology in the teaching-learning process is increasingly recognized globally, with significant implications for educational practices in Ethiopia. The Ethiopian government has also the main goal of managing the education system to produce quality citizens who are ready to face the dynamics of globalization.

While technology facilitates improved access, flexibility, and efficiency in education, it also presents challenges such as digital literacy and privacy concerns (Khat et al., 2024). Despite the potential benefits of digital tools, such as enhanced student engagement and personalized learning experiences, the integration of technology in Ethiopian education faces substantial challenges. Despite national initiatives such as Digital Ethiopia 2025 and the Ten Years Development Plan, the integration of digital tools in Ethiopian education remains in its infancy. While educators often possess strong subject-matter expertise, a significant "digital literacy" persists due to a lack of technical skills, inadequate infrastructure, and resistance to change (Dalelo et al., 2023; Welesilassie and Gerencheal, 2024). Current policy directives often fail to address the sociocultural barriers and systemic gaps in teacher training, necessitating comprehensive reforms and better resource allocation (Fenta et al., 2023; Paschal et al., 2024; Siahaan et al., 2024).

However, the 21st-century shift toward STEM education has catalyzed a move away from traditional methods. Modern tools-specifically Dynamic Mathematics Software (DMS) like GeoGebra-are now recognized as essential for making abstract concepts concrete, enhancing instructional efficiency, and fostering deeper mathematical engagement (MoSHE, 2020; Wassie and Zergaw, 2019). Overcoming existing barriers to digital literacy is therefore critical to transitioning toward the learner-driven, technology-enhanced education envisioned in Ethiopia's strategic frameworks (Alemu, 2017; Martin et al., 2023).

Modern conceptions of teacher knowledge have shifted toward the specialized skills required to plan and manage technology-enhanced mathematics classrooms. Central to this

evolution is the Technological Pedagogical Content Knowledge (TPCK) framework, which extends Shulman's (1987) foundational "Pedagogical Content Knowledge" (PCK). Unlike isolated knowledge sets, the TPCK model emphasizes the dynamic interaction and intersection of three core domains: content, pedagogy, and technology (Kassa, 2014; Koehler & Mishra, 2008). This theoretical framework asserts that effective teaching with technology is not merely an additive process but an integrated comprehension of how these domains influence one another to improve student learning outcomes. According to MoE (2014), all Ethiopian Universities are expected to use technology in their teaching to enhance the learning experience in Mathematics. But, In Ethiopia, UMTs still argue that the primary focus in teaching Mathematics should be equipping prospective teachers with strong subject matter knowledge (Kassa, 2014) and technological knowledge in Ethiopian teacher education has been overlooked. Moreover, traditional teaching methods in Ethiopian Universities are considered as outdated and incompatible with the active learning needs of the 21st century.

Ethiopian education is traditional and teacher-centered, characterized by a deep-rooted tradition of lecturing and rote learning (Derebssa, 2006; Taye et al., 2022). Despite national policy shifts toward student-centered learning starting with the 1994 Education and Training Policy, the "lecture method" continues to dominate most Ethiopian schools and higher education institutions (Abay and Marishane, 2023; Tadesse and Daniel, 2016; Derebssa, 2006). Dewey (1915/2016, p. 167) asserts, "*If we teach today's students as we taught yesterday's, we robe them tomorrow*". Few studies have been conducted in Ethiopia on the use of technology in mathematics education at the university or school level, particularly when it comes to teaching using open-access software like GeoGebra. Analyses of related works of literature indicate that there are positive effects of using mathematical software (GeoGebra) in terms of students' achievement, attitude to learning, and perceptions of mathematics. UMTs are also the key important facilitators and followers of the teaching and learning activities at universities for the contents of Mathematics, as they control and check the basic concepts up to the advanced coursework in mathematics and engineering. This study will also align with the Ministry of Education's strategy for Higher Education in Ethiopia and the importance of ICT in providing high-quality, cost-effective education, and the country's broader digital transformation goals (MoE, 2023).

Finally, though the use of GeoGebra in other regions has been shown a positive influence on students' achievement, the impact of GeoGebra training on UMTs' teaching practices: perceptions, beliefs, skills, and extent of using the software in teaching mathematics is remained underexplored in the Ethiopian HEIs context. Thus, this research article intends to determine whether or not the GeoGebra training intervention has a significant effect on UMTs' perceptions, beliefs, skills, and extent of GeoGebra usage. In order to discuss the effect of GeoGebra training intervention on the UMTs' teaching practices a research question was stated as: To what extent does the DMS-GeoGebra training influence UMTs' perceptions, beliefs, skills, and extent of GeoGebra usage? In particular, the null and possible research hypotheses to be tested were:

H$_{-0}$ The training intervention of Mathematical Software-GeoGebra in teaching mathematics has no statistically significant effect on the UMTs' perceptions, beliefs, skills, and their extent of GeoGebra usage.

H$_{-1}$ There is a statistically significant difference in UMTs' perceptions, beliefs, skills, and extent of GeoGebra usage pre- and post- intervention.

2. METHODS AND MATERIALS

This study integrates positivist and interpretivist perspectives to address both quantitative and qualitative data. The data were gathered through pre- and post-survey questionnaires and interviews with lecturers and above from the selected universities in the Tigray region. The research design employed a mixed approach, specifically a sequential design, to collect both types of data (Cohen et al., 2007; Creswell, 2014). The researchers used mixed research methods, gathering data sequentially to merge quantitative and qualitative approaches. This approach facilitated a more comprehensive understanding of the research problem. The mixed research method also allowed for the exploration of multiple data collection methods, various perspectives, and diverse forms of data analysis, ultimately revitalizing the study's conclusions (Schoonenboom and Johnson, 2017).

2.1. Study Area

This research was conducted across the four Northern Ethiopian universities in Tigray region (Fig 1). From these four universities, three were selected as data sources, with one university purposely designated for the pilot study and the remaining three participating in the main study involving UMTs as participants.

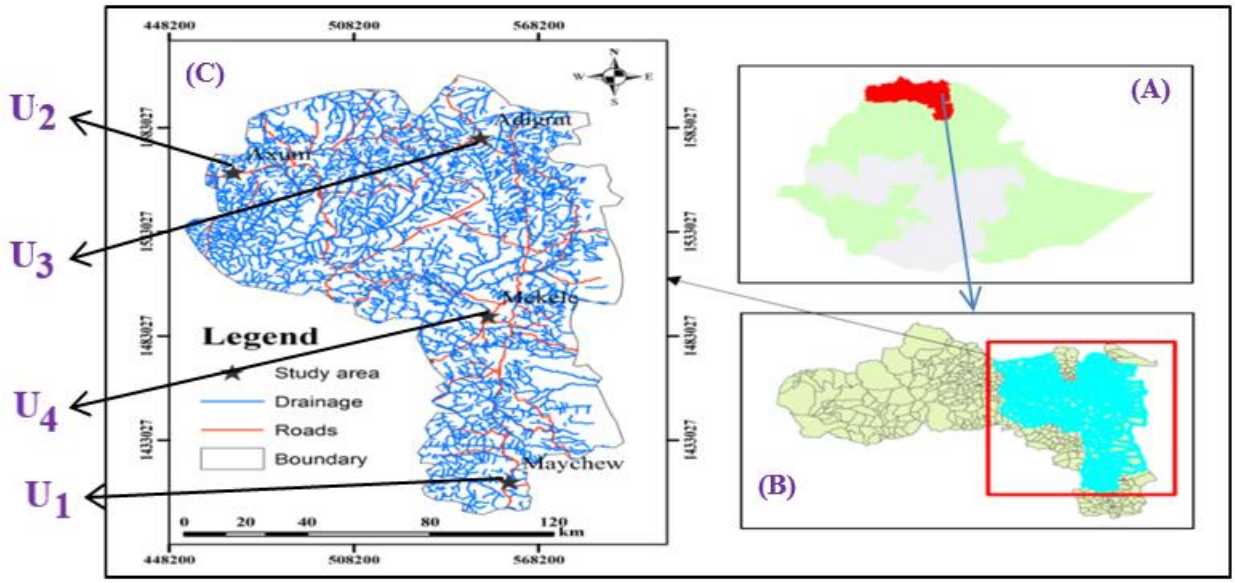


Figure 1. Map of (A) Ethiopia, (B) Tigray and (C) Study Area.

2.2. Participants, Sample and Sampling Techniques

The study included UMTs with an academic rank of lecturer or above from the four Northern Ethiopian Cluster Universities - U_1 - U_4 in the department of mathematics. For this study, U_1 - U_3 were the main focus, while U_4 was chosen for the pilot study. For the main study, a total of 96 UMTs participated: 52, 28, and 16 from U_1 - U_3 respectively participated. The statistical samples for this study consist of both male and female UMTs from the selected universities whose academic rank is lecturer and above. The participants of this study were selected using convenience sampling method. As indicated above, this study utilized both quantitative and qualitative methods. For the quantitative aspect, the study encompassed all UMTs with academic ranks of lecturer and above in the Mathematics department from the three selected Northern Ethiopian cluster universities. For the qualitative data collection, the researchers choose a sub-sample of UMTs (n = 11) mathematics teachers from the universities (U_1 - U_3) using simple random sampling and all department heads (3) using a purposive sampling method for the interviews purpose. The recordings were conducted based on their consent, and comprehensive notes were taken during the interviews. Finally, to check whether the GeoGebra training intervention had brought a significant difference or not in the UMTs' perceptions, beliefs, skills, and their extent of GeoGebra usage, the researchers conducted pre- and post-survey questionnaires (five-point Likert scales), and structured and unstructured interviews with both the UMTs participating in the study and the mathematics departments head. The materials used

in the study included a personal computer (PC laptop), the pre- and post- survey questionnaires, structured and unstructured interviews, the mathematical software (GeoGebra), and the statistical software SPSS-20 for data analysis.

2.3. Reliability and Validity of the Instruments

During a pilot study, the researchers evaluated the reliability and validity of the research instruments on a pilot group of UMTs with an academic rank of lecturer and above at U_4. This allowed the researchers to identify the implementation difficulties, establish a time schedule for the main study, and make any necessary adjustments to the initial draft before proceeding with the actual study. An item with a Cronbach's alpha value equal to or greater than 0.7 is considered acceptable, indicating reasonable reliability (George and Mallery, 2003). To this end, the pilot study revealed that the internal consistency reliability using Chronbach's alpha for the UMTs' perceptions, beliefs, skills to use the DMS-GeoGebra, and extent of GeoGebra usage were found .926, .914, .891, and .918 respectively before the training as indicated in table 1; and the UMTs' responses to the post-survey questionnaires a Cronbach alpha was computed and found to be .883, .853, 0.893, and .890 respectively which are all above the minimum requirement (0.70) indicate that there is no problem of reliability in the instruments related to the variables: perceptions on GeoGebra software (five items), beliefs toward the software (four items), skills in using the software (four items), and extent of using the software-GeoGebra (three items).

Table 1. Reliability Statistics of the instruments of the variables.

Variables	***No. of Items***	***Cronbach's Alpha***	***Cronbach's Alpha After Items Deleted***	***Updated No. of Items***
UMTs' Perceptions on GeoGebra	9	.926	.926	9
UMTs' Beliefs toward GeoGebra	10	.914	.911 (#7)	9(#7 has negative inter-item correlation with #4)
UMTs' Skills in using GeoGebra	10	.891	.925 (#6)	9(#6 has negative inter-item correlation with all items)
UMTs' Extent of using GeoGebra	10	.918	.918	10

Note: According to George and Mallery (2003), Cronbach's alpha**:** ≥ 0.9 - Excellent, ≥ 0.8 - Good, ≥ 0.7- Acceptable, ≥ 0.6 - Questionable, > 0.5 - Poor, and ≤ 0.5 – Unacceptable.

Face validity, construct validity, and content validity were used to assess the instruments validity using experts' review. Colleagues also assist in checking face and content validity, while theoretical background and literature reviews were employed to address the construct validity.

The inter-item correlation of each variable from the pilot study again revealed as indicated in table 2.

Table 2. Inter-Item Correlation Matrix (n=16).

Variables		***Beliefs***	***Perceptions***	***Skills***	***Mean***	***Std. Deviation***
UMTs' Beliefs toward GeoGebra	Pearson Correlation	1			4.0250	0.73851
	Sig. (2-tailed)					
UMTs' Perceptions on GeoGebra	Pearson Correlation	.826**	1		3.8611	0.92207
	Sig. (2-tailed)	.000				
UMTs' Skills in Using GeoGebra	Pearson Correlation	.040	.025	1	2.4500	0.73030
	Sig. (2-tailed)	.893	.932			
UMTs' Extent of GeoGebra Usage	Pearson Correlation	-.002	.155	.581*	1.9625	0.95210
	Sig. (2-tailed)	.995	.598	.029		

Note: ** Correlation is significant at the .01 level (2-tailed); * Correlation is significant at the .05 level (2-tailed).

Based on Cohen (1988) criteria- small: r ≥ 0.14, medium: r ≥ 0.36, large: r ≥ 0.51, and much larger: ≥ 0.70, the Pearson product correlation result of the pilot study analysis in table 2.2 shows that, the Pearson correlation of UMTs' perceptions and beliefs on the mathematical software-GeoGebra was found to be much large and statistically significant ($r = 0.826,\ P < 0.01$). Secondly, the correlation of these teachers' extent level of using the software in their teaching practice with their skills on the software-GeoGebra was again found small and statistically significant ($r = 0.281, P < 0.05$). However, the Pearson product inter-item correlation matrix revealed that the UMTs' perception on the mathematical software-GeoGebra and their skills, and extent level of using the software were found very small and small, and not statistically significant ($r = 0.025,\ P > 0.05$ and $r = 0.155,\ P > 0.05$), respectively. Moreover, the inter-item correlation of the UMTs' beliefs on the software-GeoGebra with their skills and extent level to use the software in their mathematics teaching practices were again found very small positive ($r = 0.040,\ P > 0.05$) and very small negative ($r = -0.002, P > 0.05$), respectively, and not statistically significant. Thus, the pilot study shows that skills and perceptions have almost zero correlation (r = 0.025). Similarly, beliefs and extent usage have a negative/zero correlation (r = -0.002). This suggests that teachers might believe technology is good, but that belief has nothing to do with their actual skill level and there exists a minimal shared variance; items may measure different things.

2.4. Data Organization and Analyses

This research is based on a combination of quantitative and qualitative data collected from mathematics lecturers and higher-ranking academicians at Ethiopian universities during the 2023/24 academic year using five-point Likert scale survey questionnaires and semi-structured interviews. The quantitative data was analyzed using descriptive and inferential statistical methods with the SPSS-20 software. Post-hoc comparisons of mean values were conducted at a significance level of $p < 0.05$ using the least significance difference to examine differences among UMTs in terms of their level of perceptions, beliefs, skills, and extent level of using the DMS-GeoGebra in teaching mathematics at Ethiopian Higher Education Institutions (specifically U_1 - U_3). Secondly, a total of fourteen participants comprised of eleven UMTs and three heads of departments were interviewed to discuss their practices when using the DMS-GeoGebra for teaching mathematics at their respective institutions. The participants were chosen using systematic and purposive sampling methods and the interviews followed a semi-structured guide as indicated in supplementary materials (See Appendix A); interviews were audio-recorded using a digital device and transcribed for the thematic analysis. Subsequently, the recorded audio was transcribed into text. To analyze the qualitative data, thematic analysis was conducted using the software NVivo to identify themes: Experiences of UMTs on the Software GeoGebra, Visualization of abstract concepts, and Efficiency and time-saving in Problem solving, allowing the data to enhance or explain the quantitative findings. These themes were data-driven, providing insights into UMTs' using GeoGebra in Mathematics instruction in which this constituted the data analysis.

2.5. Ethical Considerations

In order to guide this research with the basic principles of research rules, regulations, integrity, and research conduct with human subjects, an ethical clearance was obtained from the Mekelle University Institutional Review Board, hosted by the College of Health Sciences; expedited on 25/03/2024 with Notification of Protocol Approval MU-IRB 2191/2024 at Mekelle University. Moreover, as this study contains training on mathematical software-GeoGebra for UMTs as an intervention, for which three of the Northern Ethiopian Cluster Universities were involved in the study, for ethical issues the names of the universities are not mentioned throughout this research article. Thus, pseudonyms were used instead.

3. RESULTS

A Google online survey was conducted to gather information about the UMTs' perceptions on GeoGebra, beliefs toward GeoGebra, skills in using the DMS-GeoGebra, and their extent to which they use the GeoGebra software in teaching Mathematics. As shown in **Error! Not a valid bookmark self-reference.**, the response rates for the Google online survey questionnaire were 83.87% at U_1, 100% at U_2, and 80% at U_3 among the UMTs who participated in this study. In total, the overall response rate for the Google online survey administered to UMTs at the three Northern Ethiopian Universities was 87.27%, while the nonresponse rate was 12.73%. Moreover, to address the discrepancy in sample sizes between the study phases, it is essential to explicitly state that of the 96 initial participants who engaged in the pre-intervention survey, only 75 completed both the GeoGebra training and the post-intervention assessment, resulting in a 78% retention rate. The loss of 21 participants (22%) was attributed to specific factors—such as scheduling conflicts, incomplete survey submissions, or withdrawal from the training modules—to mitigate concerns regarding attrition bias. Furthermore, for the statistical integrity of the analysis, the paired-samples t-test is restricted exclusively to the 75 respondents who provided data at both time points, ensuring that the pre-to-post comparison reflects the growth of the same group of individuals.

Table 3. Response Rates of UMTs for the Online Google Survey Questionnaires.

Universities	***UMTs selected to fill out the survey***	***UMTs filled out and submitted the survey***	***UMTs did not submit the survey***
U_1	62 (100%)	52 (83.87%)	10 (16.13%)
U_2	28 (100%)	28 (100%)	0
U_3	20 (100%)	16 (80%)	4 (20%)
Total	110 (100%)	96 (87.27%)	14 (12.73%)

Table 4. UMTs Experience in Using GeoGebra to Teach Mathematics.

			University			***Total***
			U1	***U2***	***U3***	
UMTs' experience in using the DMS-GeoGebra to teach Mathematics contents	Yes	N (%)	10 (58.8%)	5 (29.4%)	2 (11.8%)	17 (100.0%)
		% of Total	10.4%	5.2%	2.1%	17.7%
	No	N (%)	42 (53.2%)	23 (29.1%)	14 (17.7%)	79 (100.0%)
		% of Total	43.8%	24.0%	14.6%	82.3%
Total		N (%)	52 (54.1%)	28 (29.2%)	16 (16.7%)	96 (100.0%)

The descriptive analysis shows that, as indicated in table 4, majority of the UMTs 79 (82.3%) in the three Northern Ethiopian Universities have no experience in using the DMS-GeoGebra to teach Mathematics contents. The rest 17 (17.7%) have an experience in using the software-GeoGebra for teaching. This baseline data confirms a critical gap in software utilization, as over 80% of UMTs had never integrated GeoGebra into their pedagogy despite national policy mandates.

3.1. Normality and Homogeneity Variance Tests of the Quantitative Data

Table 5 shows the descriptive statistics of the variables; UMTs' perceptions, beliefs, skills, and extent of using the dynamic mathematical software-GeoGebra in their mathematics teaching practices.

As it could be seen in table 5, the skewness of the scale variables was computed to determine the distribution of the data. According to Mulat (2023), Cohen (1988), and Aweke (2019) if the skewness is between plus or minus one (± 1.0) and the $Z_{skewness}$ is between ± 3.29, which is computed as the ratio of skewness statistics to its standard error (Ghasemi & Zahediasl, 2012), which is the rule of thumb of approximately normal distribution. Moreover, Kim (2013) indicated that a Z-score could be obtained by dividing the skewness values or excess kurtosis value by their standard error. He further elaborated that for medium-sized samples ($50 \leq n < 300$) a Z-score of ± 3.29 is sufficient to establish normality of the data.

Table 5. Descriptive Statistics.

Variables	***N***	***Minimum***	***Maximum***	***Mean***	***Std. Dev.***	***Variance***	***Skewness***	
	Statistic	***Statistic***	***Statistic***	***Statistic***	***Statistic***		***Statistic***	***Std. Error***
UMTs' Perceptions	96	2.00	5.00	3.9444	0.68645	0.471	-0.541	0.246
UMTs' Beliefs	96	2.22	5.00	4.1424	0.65501	0.429	-0.504	0.246
UMTs' Skills	96	1.00	5.00	2.6887	1.16797	1.364	0.189	0.246
UMTs' Extent of GeoGebra Usage	96	1.00	5.00	2.2875	1.11773	1.249	0.494	0.246

Hence, all the variables of this study are at least approximately normal, which is one of the assumptions for using parametric tests. Using this thump rule, all the variables were approximately normal as $-0.541 < skewness < 0.494$.

As indicated in table 6, it can be seen that the Homogeneity of variance for the variables beliefs, skills, and extent level of GeoGebra usage holds, as the Levene's test of equality of

variances met (F (2,93) = 0.512, p > .05; F (2,93) = 1.916, p > .05; and F (2,93) = 1.642, p > .05), respectively.

Table 6. Levene's Test (Homogeneity of Variance) of the Variables.

Variables	***Levene Statistic***	***df1***	***df2***	***Sig.***
UMTs' Beliefs toward GeoGebra	0.512	2	93	0.601
UMTs' Perceptions on GeoGebra	3.361	2	93	0.039
UMTs' Skills in Using GeoGebra	1.916	2	93	0.153
UMTs' Extent of GeoGebra software Usage	1.642	2	93	0.199

On the other hand, Levene's test of Homogeneity of the variable perceptions does not hold, since the Levene's test of equality of the variance is not met (F(2,93) = 3.361, p < .05) indicates that there is a significant difference of variance with respect to the perception of the UMTs on the DMS-GeoGebra indicates to use an Independent-samples Kruskal-Wallis nonparametric test to see the difference between the UMTs groups with respect to their perceptions (see also Table 9).

3.2. Analysis of Group Difference in the Variables

Before addressing the research question, the researchers first aimed to determine whether there were differences among the groups (U_1 - U_3) regarding their perceptions, beliefs, skills, and extent of GeoGebra software utilization in teaching Mathematics. This analysis will involve UMTs from three universities with academic ranking of lecturer and above (Table 7).

Table 7. Descriptive Statistics of the Three Groups in the Variables of the Study.

Variables		***N***	***Mean***	***Std. Deviation***	***Std. Error***	***95% Confidence Interval for Mean***	
						Lower Bound	***Upper Bound***
UMTs' Beliefs toward GeoGebra	U_1	52	4.1004	0.63819	0.08850	3.9228	4.2781
	U_2	28	4.2778	0.60140	0.11365	4.0446	4.5110
	U_3	16	4.0417	0.79388	0.19847	3.6186	4.4647
	Total	96	4.1424	0.65501	0.06685	4.0096	4.2751
UMTs' Perceptions on GeoGebra	U_1	52	3.9573	0.68464	0.09494	3.7667	4.1479
	U_2	28	3.9683	0.54337	0.10269	3.7576	4.1790
	U_3	16	3.8611	0.92207	0.23052	3.3698	4.3524
	Total	96	3.9444	0.68645	0.07006	3.8054	4.0835
UMTs' Skills in Using GeoGebra	U_1	52	2.5385	1.21744	0.16883	2.1995	2.8774
	U_2	28	3.1468	1.15036	0.21740	2.7008	3.5929
	U_3	16	2.3750	0.80213	0.20053	1.9476	2.8024
	Total	96	2.6887	1.16797	0.11921	2.4520	2.9253
UMTs' Extent of GeoGebra software Usage	U_1	52	2.1000	1.01826	0.14121	1.8165	2.3835
	U_2	28	2.8214	1.22787	0.23205	2.3453	3.2975
	U_3	16	1.9625	0.95210	0.23803	1.4552	2.4698
	Total	96	2.2875	1.11773	0.11408	2.0610	2.5140

The mean and standard deviation were calculated to summarize and describe the data sets obtained from the UMTs whose academic rank is lecturer and above. The variables analyzed included perceptions, beliefs, skills, and extent of using the software GeoGebra at their respective universities (U_1 - U_3). The results presented in table 7 indicate significant variations in the mean scores among the three groups of UMTs regarding their skills with GeoGebra (Mean = 2.5385, 3.1468, and 2.3750, with SD = 1.21744, 1.15036, and 0.80213, respectively). There were also differences in the extent of using the software to teach mathematics (Mean = 2.1000, 2.8214, and 1.9625, with SD = 1.01826, 1.22787, and 0.95210, respectively) across the three groups of UMTs at U_1 - U_3.

Conversely, table 7 and 9 reveal that there were insignificant variations in mean scores among the three groups regarding their perceptions of using GeoGebra (Mean = 3.9573, 3.9683, and 3.8611, with SD = 0.68464, 0.54337, and 0.92207, respectively), and their beliefs about the software (Mean = 4.1004, 4.2779, and 4.0417, with SD = 0.63819, 0.60140, and 0.79388, respectively) for the three groups at U_1 - U_3. Overall, at the beginning of the study, the three groups appeared nearly similar concerning the variables of perception and beliefs. However, these results should not be generalized with a high level of confidence and significance.

As shown in table 8, the study results indicate that there were no statistically significant differences between the UMTs groups regarding their beliefs ($F(2,93) = 0.892$, $p > 0.05$).

Table 8. One-way ANOVA results of the three UMTs' Group to the variables.

Variables		***Sum of Squares***	***df***	***Mean Square***	***F***	***Sig.***	***Partial Eta-squared***
UMTs' Beliefs toward GeoGebra	Between Groups	0.767	2	0.384	0.892	0.413	0.019
	Within Groups	39.991	93	0.430			
	Total	40.758	95				
UMTs' Skills in Using GeoGebra	Between Groups	8.625	2	4.312	3.315	0.041	0.067
	Within Groups	120.971	93	1.301			
	Total	129.596	95				
UMTs' Extent of GeoGebra software Usage	Between Groups	11.500	2	5.750	4.989	.009	0.097
	Within Groups	107.185	93	1.153			
	Total	118.685	95				
	Total	4141.833	95				

However, significant differences were found among the three UMTs groups in terms of their skills in using GeoGebra ($F(2,93) = 3.315$, $p < 0.05$, $\eta^2 = .067$), and their extent of using it for teaching Mathematics ($F(2,93) = 4.989$, $p < 0.01$, $\eta^2 = .097$). Additionally, as indicated in table 9, the Independent-samples Kruskal-Wallis nonparametric test showed that the UMTs'

perceptions of the dynamic mathematical software GeoGebra were similar across the three university groups (F (2,96) = 0.073, p = 0.964 > 0.05).

Table 9. Results from Kruskal-Wallis test for the UMTs' Perceptions (n=96).

Null Hypothesis	***Test***	***Test Statistic***	***df***	***Asymptotic Sig. (2-sided test)***	***Decision***
The distribution of UMTs' perception on GeoGebra is the same across the three Universities	Independent Samples Kruskal-Wallis test	0.073	2	0.964	*Retain the null hypothesis*

Note: *The significance level is 0.05.*

As it could be easily seen in table 10, the skewness of the scale variables was computed to determine the distribution of the data after the GeoGebra training had given; and according to Mulat (2023), Cohen (1988), and Aweke (2019) if the skewness is between ± 1.0, which is the rule of thumb of approximately normal distribution which is one of the assumptions for using parametric tests. Using this thump rule, all the variables were approximately normally distributed as -0.566 < skewness < 0.504.

Table 10. Descriptive Statistics of UMTs' Post-GoGebra Training Intervention on the Four Variables.

Variables	***N***	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***	***Variance***	***Skewness***	
	Statistic	***Statistic***	***Statistic***	***Statistic***	***Statistic***	***Statistic***	***Statistic***	***Std. Error***
Post-Beliefs	75	4.00	5.00	4.5300	0.34622	0.120	0.030	0.277
Post-Perceptions	75	3.80	5.00	4.4400	0.34328	0.118	0.504	0.277
Post-Skills	75	3.00	5.00	4.3533	0.44092	0.194	-0.566	0.277
Post-Extent Level	75	4.00	5.00	4.6667	0.34658	0.120	-0.519	0.277

Table 11. Post-Intervention Levene's Test (Homogeneity of Variance) of the Variables.

Variables	***Levene Statistic***	***df1***	***df2***	***Sig.***
Post-Beliefs	0.076	2	72	0.927
Post-Perceptions	0.020	2	72	0.980
Post-Skills	0.261	2	72	0.771
Post-Extent Level	0.022	2	72	0.978

As shown in table 11, it can be seen that the Homogeneity of variance for the variables Post-beliefs, Post-perceptions, Post-skills, and Post-extent of using the software holds, as the Levene's test of equality of variances met (F(2,72) = .076, p = .927 > .05; F(2,72) = .020, p = .980 > .05; F(2,72) = .261, p = .771 > .05; and F(2,72) = .022, p = .978 > .05), respectively;

indicates that there is no significant difference of variance with respect to all the variables of the UMTs on the DMS-GeoGebra after the GeoGebra training intervention had given.

3.3. Analysis of Group Difference on Post-GeoGebra Training

During the post-intervention survey the UMTs' progress change was elicited by a post-survey questionnaire. The questionnaire was distributed to the UMTs who took the GeoGebra training only to determine their beliefs toward using GeoGebra, perceptions on the GeoGebra, skills in using the software, and extent of using the GeoGebra software. The results of the analysis of the responses to the questionnaire reflect that UMTs have high beliefs toward using the software (with an overall mean of M = 4.533), perceptions on the software-GeoGebra (an overall mean of M = 4.440), skills in using the software (with an overall mean of M = 4.355), and extent of using the software-GeoGebra in their teaching practices (with an overall mean of M = 4.67).

Scores obtained from the post-GeoGebra training intervention using the four different instruments namely: UMTs' perceptions on GeoGebra software, beliefs toward the software, skills in using the software, and their extent of using the software-GeoGebra post-survey questionnaire means were analyzed by applying One-Way ANOVA which compares the means of the three University groups as presented in tables 12 and 14, after the assumptions tested.

Table 12. Descriptive Statistics of the Three Groups in the Variables after the GeoGebra Training Intervention.

Groups	***N***	***Post-Beliefs***		***Post-Perception***		***Post-Skills***		***Post-Extent Level***	
		Mean	***Std. Dev.***	***Mean***	***Std. Dev.***	***Mean***	***Std. Dev.***	***Mean***	***Std. Dev.***
U_1	40	4.5250	0.34807	4.4400	0.34254	4.3563	0.43812	4.6583	0.34991
U_2	19	4.5789	0.35407	4.4526	0.33890	4.3684	0.38522	4.7719	0.33431
U_3	16	4.4844	0.34724	4.4250	0.37148	4.3281	0.53008	4.5625	0.33816
Total	75	4.5300	0.34622	4.4400	0.34328	4.3533	0.44092	4.6667	0.34658

Using the descriptive statistics (SPSS output result as presented in table 12) showed that the mean scores in U_1 (Mean = 4.525), U_2 (Mean = 4.5789), and U_3 (Mean = 4.844) on beliefs toward using the software; U_1 (Mean = 4.44, U_2 (Mean = 4.4526), and U_3 (Mean = 4.4250) on GeoGebra perceptions; U_1 (Mean = 4.3563), U_2 (Mean = 4.3684), and U_3 (Mean = 4.3281) on GeoGebra skills; U_1 (Mean = 4.6583), U_2 (Mean = 4.7719), and U_3 (Mean = 4.5625) on extent of using the software-GeoGebra when checked after the GeoGebra training intervention were nearly the same. The difference is not also significant at .05 levels (Table 13).

To determine the statistical difference if any between the three groups regarding the four variables, the one-way ANOVA was used and summarized in table 13. After the training

intervention, the result of the study shows that there was no statistically significant mean difference on UMTs' beliefs toward using the software ($F(2,72) = 0.327$, $p = 0.722 > 0.05$); perceptions on GeoGebra software ($F(2,72) = 0.027$, $p = 0.973 > 0.05$); skills in using it ($F(2,72) = 0.037$, $p = 0.964 > 0.05$); and again on their extent of using the software-GeoGebra ($F(2,72) = 1.638$, $p = 0.201 > 0.05$) among the three groups of UMTs.

Table 13. One-Way ANOVA Summary Table Comparing Groups on the variables Post Training Intervention.

Sources		***df***	***Sum of Squares***	***Mean Square***	***F***	***Sig.***
Post-Beliefs	Between Groups	2	0.080	0.040	0.327	0.722
	Within Groups	72	8.790	0.122		
	Total	74	8.870			
Post-Perceptions	Between Groups	2	0.007	0.003	0.027	0.973
	Within Groups	72	8.713	0.121		
	Total	74	8.720			
Post-Skills	Between Groups	2	0.015	0.007	0.037	0.964
	Within Groups	72	14.372	0.200		
	Total	74	14.387			
Post-Extent of Using	Between Groups	2	0.387	0.193	1.638	0.201
	Within Groups	72	8.502	0.118		
	Total	74	8.889			

After the GeoGebra training intervention, from the One-Way ANOVA Summary table 13, all the UMTs in the three groups does not show any significance difference on their beliefs, perceptions, skills, and extent of using the software-GeoGebra. Hence, it could be possible to conclude that UMTs of both groups have similar mean scores on their beliefs, perceptions, skills, and extent of using the GeoGebra software after the training.

3.4. Statistical Analysis of the Mean Gains of UMTs on the Variables within the Groups

The results of all groups on the four variables (Beliefs, Perceptions, Skills, and Extent of Using) measured before and after the GeoGebra training intervention was used to examine the advancement from pretest to posttest. In this case, each group participants is measured twice (before and after the GeoGebra training intervention), by providing a pair of observations. A pair samples t-test was employed to see the mean gains of the UMTs' beliefs, perceptions, skills, and extent of using from pretest to posttest on the software-GeoGebra. Therefore, paired samples t-test helps to see the progression of each group from pretest to posttest (the difference within the group) on the four variables as presented in table 14.

The data obtained by measuring the four variables (before and after the training intervention) satisfies all the assumptions to apply the paired samples t-test: (1) the independent variables' levels (groups) are paired, or matched; (2) the variables are normally distributed in during both before and after the GeoGebra training intervention (skewness criteria was checked) (see Tables 5 and 10).

Table 14. Paired Samples t-test on Mean Gains of the UMTs' on the Four Variables Scores by Groups.

Mean Gain of Subjects	***Paired Differences***					***t***	***Df***	***Sig. (2-tailed)***	***effect size Cohen's d***
	Mean	***Std. Deviation***	***Std. Error Mean***	***95% Confidence Interval of the Difference***					
				Lower	***Upper***				
Beliefs: Pre-Post	0.38926	0.76719	0.08859	0.21275	0.56577	4.394	74	0.000	0.5074
Perceptions: Pre-Post	0.50370	0.79791	0.09213	0.32012	0.68729	5.467	74	0.000	0.6313
Skills: Pre-Post	1.64815	1.18103	0.13637	1.37642	1.91988	12.086	74	0.000	1.3955
Extent of Using: Pre-Post	2.28800	1.23033	0.14207	2.00493	2.57107	16.105	74	0.000	1.8597

Based on the descriptive statistics (Table 14), UMTs have got positive mean gains from their pre-GeoGebra training to post-GeoGebra training intervention on beliefs toward using the GeoGebra software (Mean = .38926, SD = .76719); and the paired samples t-test also indicated that the mean gain is statistically significant between the pre and post- intervention within the groups (*t(74) = 4.394, p < .001, d = .5074*). Similarly, from the results of table 14, UMTs have got positive mean gains from pre-intervention to post-intervention on their perception on the GeoGebra software (Mean = .50370, SD = .79791); and the mean gain is statistically significant within the groups (*t(74) = 5.467, p < .001, d = .6313*). Moreover, UMTs again show positive progress from pre-GeoGebra training intervention to post-intervention on their skills in using and extent of using the software in their Mathematics teaching practices within the three groups (Mean = 1.64815, SD = 1.18103; Mean = 2.288, SD = 1.23033); and there is statistically significant mean gain with in the groups (*t(74) = 12.086, p < .001,* d *= 1.3955; t(74) = 16.105, p < .001, d = 1.8597*). Generally, due to the GeoGebra training intervention, UMTs got better mean gains on their extents of beliefs toward using GeoGebra, perceptions on GeoGebra, skills in using it, and extent levels of using the software in their Mathematics teaching practices.

Figure 2 revealed that UMTs increase their beliefs toward using the software (from M = 4.1407 to 4.5300), perceptions on the software (from M = 3.9363 to 4.4400), skills in using the software (from M = 2.7052 to 4.3533), and extent of using the software-GeoGebra in

Mathematics teaching practices after the GeoGebra training (from M = 2.3787 to 4.6667). This means the intervention has brought positive effect on UMTs' extent of perceptions on GeoGebra, beliefs toward the DMS-GeoGebra, skills in using the GeoGebra software, and extent usage of the software in their Mathematics teaching practices.

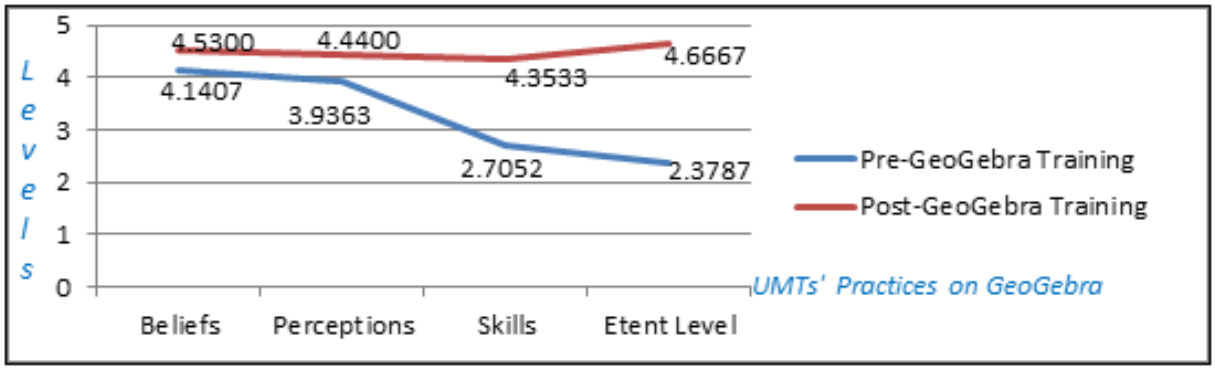


Figure 2. Line Graph Presentations of Mean scores of UMTs before and after the GeoGebra Training.

3.5. UMTs' Interview Data Analysis

The interviewer discussed the importance of using GeoGebra software in teaching and learning mathematics. The interviewee, who had no prior experience with the software, found the training to be fascinating and essential for future use. GeoGebra is a basic teaching aid for complex concepts such as matrices, limits, derivatives, integrations, and their applications. It can help to illustrate abstract mathematical concepts graphically, such as functions and trigonometric functions, helping students understand the concept better after the given concept is introduced.

Theme 1: Experiences of UMTs on the Software GeoGebra

Before this training, the interviewees had no experience with the mathematical software GeoGebra but now find it interesting and recommend it. They also had limited experience in evaluating limits, derivatives, integrations of functions, and operations of matrices. They mentioned using Latex for document preparation and printing in PDF format, but they now found GeoGebra dynamic and helpful for developing HTML language five web applications, visualization of three-dimensional objects, mobile application programs, and data analysis using its spreadsheet perspectives.

Theme 2: Visualization of abstract concepts

The researchers also asked a question to the interviewees, 'Do you think that the Mathematical Software-GeoGebra will help you with your teaching'? Why? To this end, some of them said that:

> *Sure, from the GeoGebra training, I have observed that teaching and learning using this software is very important because these training days were fascinating me as I have no any experience about the mathematical software-GeoGebra. But, from the result of this training, I try to touch the concepts of matrices, limits, derivatives, integrations and their applications. The most important aspect of GeoGebra is its ability to show algebraic and geometrical concepts simultaneously in one interactive window. So, it is very fascinating me and for sure for the future it will be very important.*

Theme 3: Efficiency and time-saving in Problem Solving.

Another interviewee also replied as:

> *Sure, as I observed on the training days, I am sure this GeoGebra is basic teaching aids especially for those topics complex concepts as well as to visualize those complex concepts geometrically again for those abstract technically as well as conceptually those concepts in order to understand them, this GeoGebra software is very essential for us not only for me as you observe in the training session all the instructors were also very eager to teach the concepts of matrices and calculus-I practically using this software effectively to solve problems within short period of time*

In conclusion, the interviewees found GeoGebra to be an essential tool for teaching mathematics, *providing a convenient environment for teaching and learning, simplifying problem-solving and enhancing efficiency in understanding complex concepts* (U_3, 2023). The training provided by GeoGebra software offers numerous advantages for teachers and students. It *allows for the visualization of abstract concepts geometrically and graphically, helping to remember knowledge that may have been forgotten before* (U_2, 2023). The software is open, easily accessible, and interactive, making it suitable for solving complex mathematical equations and sketching graphs. The training also highlighted the importance of GeoGebra in solving mathematical concepts, particularly linear algebra, calculus-I parts, and graphs in detail. *It helps solve problems that are difficult to solve manually and saves time in solving lengthy problems*

(U_1, 2023). By simply entering variables, parameters, and terms, *GeoGebra can process and provide results quickly by saving time and energy* (U_3, 2023).

4. FINDINGS AND DISCUSSION OF THE RESULTS

The objective of this study was to determine whether or not the GeoGebra training has a significant effect on UMTs' perceptions on the GeoGebra software, beliefs toward the software-GeoGebra, skills in using the DMS-GeoGebra, and extents of using the software to teach Mathematics; to test the hypothesis: 'There is a statistically significant difference in UMTs' perceptions, beliefs, skills, and extent of using the DMS-GeoGebra in teaching Mathematics before and after the GeoGebra training intervention'. At the beginning of the study, the results from both groups indicated that there were significant mean differences in their skills to use the GeoGebra software and in the extent to which they incorporated it into their mathematics teaching practices, in which the three groups were nearly similar in their perceptions on the software-GeoGebra and beliefs toward the software.

However, after the GeoGebra training intervention, all the UMTs in the three groups did not have any significance difference on their beliefs, perceptions, skills, and extent usage of the software-GeoGebra in their teaching practices; hence, UMTs in the three groups have similar mean scores on their perceptions on the GeoGebra, beliefs toward GeoGebra, skills in using the software, and extent of using the GeoGebra software in mathematics teaching practices as indicated in. Finally, UMTs demonstrated significant increase across all the four domains from their pre-GeoGebra training to post-GeoGebra training intervention on their beliefs toward using the GeoGebra software, perception on the GeoGebra software, skills in using and extent of using the software in their Mathematics teaching practices within the three groups; and the paired samples t-test also indicated that the mean gain is statistically significant between the pre and post- intervention within the groups.

Generally, due to the GeoGebra training intervention, UMTs got significant mean gains on their extents of beliefs toward using GeoGebra, perceptions on GeoGebra, skills in using it, and levels of using the software in their Mathematics teaching practices. This implies that the GeoGebra training has a statistically significant effect on UMTs' perceptions, beliefs, skills, and extent of using the software in their Mathematics teaching practices. As there is a statistically significant difference on the UMTs' perceptions on GeoGebra, beliefs toward the software, skills

to use the GeoGebra software, and extent of using it in Mathematics teaching at 0.05 level of significance which indicates that the null hypothesis that 'The training intervention of the DMS-GeoGebra in teaching Mathematics doesn't have an effect on UMTs' perceptions, beliefs, skills, and extents of using the software' is rejected. This, in turn, implies that the alternate research hypothesis is supported: **H-1**, there is a statistically significant difference on UMTs' perceptions, beliefs, skills, and extent of using the software-GeoGebra before and after the GeoGebra training intervention is retained.

Research findings also confirmed that the GeoGebra training significantly impacts UMTs' perceptions, beliefs, skills, and usage levels. Research indicates that teachers who engage in GeoGebra-mediated professional development experience positive shifts in their pedagogical beliefs and technology dispositions, enhancing their competence and intentions to integrate technology into their teaching practices (Benning et al., 2023). The UMTs *demonstrate and visualize function of two variables to create a surface and their partial derivatives to represent slopes in specific directions, linear transformations dynamically; and the formal definitions of limit using sliders* (U_1-U_3; 2023), which revealed that the core professional evolutions:

Dynamic Tech Mastery - transitioning from basic ICT use to real-time integration of algebraic and geometric data;

Enhanced Visualization - developing the "spatial literacy" to project complex, abstract 3D concepts that traditional whiteboards cannot capture;

Conceptual Synthesis - creating a more unified understanding of mathematical branches (algebra, geometry, and data) for more robust instruction; and

Instructional Agility - strengthening real-time problem-solving skills by managing technical hurdles and student inquiries in a digital environment. GeoGebra facilitates the visualization of complex mathematical concepts, thereby improving teachers' ability to present material effectively and engage students (Muslim et al., 2023; Pancahayani et al., 2022).

Furthermore, training programs have demonstrated that teachers can successfully utilize GeoGebra for creating interactive lessons, which fosters deeper understanding and problem-solving skills among students (Majerek, 2014; Haciomeroglu et al., 2009). This supports the Technological Pedagogical Content Knowledge (TPCK) framework, which extends the Shulman's (1987) foundational "Pedagogical Content Knowledge" (PCK). Overall, the

integration of GeoGebra in teacher training not only enhances instructional quality but also transforms teachers' attitudes toward technology in Mathematics education. This study also shows that UMTs' want to use technology (high beliefs), but, can't (low skill) and this proves that the training was the missing bridge

The findings of this research are also consistent with studies Salami and Spangenberg (2024) and Wang (2024) which argued that the integration of GeoGebra in Mathematics education significantly influences Mathematics teachers' perceptions, beliefs, skills, and usage levels in which they considered the software as 'pedagogical mediator' that improves student discovery and conceptual depth than as just a calculator after the training. Research indicates that GeoGebra enhances teachers' pedagogical approaches and fosters a positive attitude toward technology usage in the classroom. For instance, Salami and Spangenberg, 2024) stated that GeoGebra can improve teachers' performance and attitudes toward Mathematics, suggesting that teachers who embrace this software can foster better learning outcomes. Moreover, the integration of GeoGebra into teacher education programs has been recommended to enhance teachers' beliefs and practices regarding technology use in Mathematics instruction (Wang, 2024).

4.1. Limitations of the Study

The study has several limitations, including a small sample size of 96 participants (during training decreased to 75) from the three Northern Ethiopian cluster universities, external factors like teachers' bias and logistical, a lack of inclusion of other Ethiopian cluster universities, and a difference in UMTs' skills and extent level of using the software in their teaching practices. Other limitations include the absence of participants due to the conflict in Tigray. These factors were anticipated limitations for the researchers, particularly, in terms of limited study duration: might affect the long-term retention of skills, sample size restrictions, and participant availability. To address the 22% dropout rate, a non-equivalent group quasi-experimental design was utilized to ensure that the analysis focused only on UMTs with complete pre- and post-intervention data, maintaining internal validity. While the study could not include all Ethiopian cluster universities due to security and logistical constraints, the researchers selected three representative universities in the northern cluster to ensure a diverse cross-section of UMTs within the accessible regions. To counter potential "teacher bias" or self-reporting inaccuracies, the study employed mixed methods. Qualitative interviews were also used to triangulate and

validate the quantitative survey findings, ensuring a more objective assessment of GeoGebra's impact. Again, to address varying baseline skill levels among UMTs, a standardized training manual and a structured intervention protocol were developed to ensure that all participants received a uniform quality of instruction, regardless of their starting point. In response to logistical hurdles and potential power/internet outages common in conflict-affected zones, training materials were provided in offline formats to ensure participants could continue practicing GeoGebra skills even without constant connectivity.

Despite these limitations, the findings of this study provide invaluable insights into the assessment of UMTs' practices in teaching mathematics at Ethiopian higher education institutions. In addition, the findings could inform policy developers and curriculum designers to consider the extent levels of UMTs' perceptions, beliefs, and skills to use the software-GeoGebra in their teaching practice at the tertiary level; and to see impact of GeoGebra training on the UMTs' extent level of using the software in teaching mathematics, their perceptions on the DMS-GeoGebra, beliefs toward the software, and skills to use the software-GeoGebra, and finally it may lead to others for further research in this area.

5. CONCLUSION AND RECOMMENDATIONS

The researchers of this study explored the effects of the DMS-GeoGebra training on the UMTs' perceptions, beliefs, skills, and extent of using the software-GeoGebra in their mathematics teaching practice at HEIs and found that before the training intervention: baseline results revealed no a statistically significant difference perceptions and beliefs among UMTs across the three universities; but, there was a statistically significant difference between the groups with respect to their skills in using the software and extent level of using the DMS-GeoGebra in their teaching practices.

Moreover, after the GeoGebra training intervention, all the UMTs in the three groups did not have any significance difference on their beliefs, perceptions, skills, and extent of using the software-GeoGebra; but, participants demonstrated significant mean gains across all four variables- perceptions, beliefs, skills, and usage – following the intervention. As a result, there is a statistically significant difference on UMTs' perceptions, beliefs, skills, and extent of using the software-GeoGebra before and after the GeoGebra training intervention. Also, mentioned that

the training effectively neutralized the initial disparities in skill levels and usage between the universities.

Finally, the researchers argued that, to deliver effective teaching-learning mathematics lessons using GeoGebra, the Ministry of Education should focus on the formal integration of DMS like GeoGebra into the national harmonized curriculum for mathematics, professional development for mathematics teachers regarding GeoGebra software, infrastructure and technology support in mathematics class rooms. HEIs should move one-off workshops and establish a system for continuous evaluation and peer-mentoring for technology-enhanced pedagogy, ensure that mathematics classrooms are equipped with the necessary ICT infrastructures, promote student engagement with the software in order to help the faculty members to become proficient in using the software-GeoGebra, and assess the impact of GeoGebra on the learning outcomes thereby enhancing mathematics education at universities. Again, the respondents suggest that UMTs should prioritize the systematic integration of GeoGebra into their instructional design in their teaching practices to achieve the goals of the teaching-learning processes needed for the 21st century. Finally, policymakers and curriculum designers should recognize and reward faculty members who successfully implement innovative digital tools in their teaching practices. By empowering University Mathematics Teachers with DMS, this study provides a scalable model for pedagogical digital transformation, directly contributing to the Digital Ethiopia 2025 strategy by bridging the digital literacy gap and fostering a tech-savvy workforce capable of driving the nation’s future digital economy.

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7. CONFLICT OF INTEREST

There is no conflict of interests.

8. REFERENCE

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