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Research Article

Challenges in integrating GeoGebra for mathematics instruction in Ethiopian universities

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This research aimed to pinpoint the barriers faced by University Mathematics teachers when integrating the Dynamic Mathematical Software-GeoGebra into their teaching methods at Ethiopian higher education institutions. The study employed a survey method with 96 participants who provided ratings using a five-point Likert scale. Furthermore, face-to-face interviews were conducted with 8 University Mathematics Teachers having academic rank Lecturer and higher during the academic year 2023/2024. The survey participants were selected using a stratified cluster sampling approach, while the interviewees were chosen through systematic and purposive sampling. The internal consistency reliability coefficient Cronbach's alpha for the barriers scale items for using GeoGebra was .798. The analysis of the responses indicated that University Mathematics Teachers face challenges in using GeoGebra in their teaching practices due to students' experience with the software, lack of access and support in using technology, University Mathematics Teachers' perceptions, beliefs, and skills in using GeoGebra, lack of funding, adequate infrastructures, training, exposure, and awareness of mathematical software, inadequate staff support, the mathematics curriculum itself, and their resistance to change. The findings of this study could also inform policy developers and curriculum designers to consider the challenges faced by University Mathematics Teachers in their teaching practice at the tertiary level, and it may lead to others for further research in this area. Finally, regular training and workshops are necessary for University Mathematics Teachers and institutions in Ethiopia as a whole.

Keywords: Barriers to use GeoGebra, Dynamic mathematical software, GeoGebra, Higher education institutions, Teaching mathematics, Technology

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1. Introduction

In the 21st century, effective teaching methods incorporate recent advancements in mathematical software, particularly the utilization of Dynamic Mathematical Software [DMS] such as GeoGebra. This tool has demonstrated its global benefits, being applied in elementary schools through to Higher Education Institutions [HEIs]. According to Tall (2019), digital technology enriches the teaching and learning of mathematics by facilitating rapid and precise numerical calculations, symbol manipulation to enhance visualization skills, and the creation of dynamic visuals to aid in comprehending abstract concepts. Tall et al. (2008, p. 207) also posit that "calculus can be taught using technology from all fields of mathematics." Hence, integrating technology into the educational framework represents an effective approach to addressing

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mathematical challenges and has the potential to enhance performance when employed with skill and expertise. In their research, Abebe and Dirbeba (2017) as well as Sebsibe et al. (2019) identified several factors contributing to the challenges Ethiopian university students face when it comes to regard mathematics as difficult. These factors include students' weak mathematics background due to teachers' poor qualifications and a lack of job opportunities outside the teaching profession. Additionally, inadequate pedagogical content knowledge exacerbates these challenges. The use of multimedia technology, specifically GeoGebra, in the teaching and learning process, can help and simplify these difficulties.

Markus Hohenwarter founded GeoGebra at the University of Salzburg in 2001, and since then, translators and open-source developers from all around the world have contributed to its development. Following a successful Kickstarter campaign, GeoGebra's offerings expanded to include versions for iPad, Android, and the Windows Store. In 2013, Bernard Parisse's Giac integrated Computer Algebra Systems [CAS] into GeoGebra's view. GeoGebra is a geometry package that allows for both graphical and algebraic input and provides programs and worksheets for download. It has received numerous educational software awards and supports STEM education worldwide. GeoGebra has gained exceptional popularity as freely downloadable multi-stage DMS, catering to all educational levels from elementary to university. It serves as interactive mathematics software for learning and teaching various mathematical disciplines, including geometry, algebra, statistics, and calculus.

GeoGebra is a versatile application that integrates the functionalities of a CAS and Dynamic Geometry Software [DGS] (Hewson, 2009; Hohenwarter et al., 2009). According to Hewson (2009), GeoGebra not only provides cost-effective solutions but also fosters collaborative learning and teaching. It can be utilized in educational settings and at home without licensing constraints, and it can be used offline once installed. It was created by Markus Hohenwarter in 2001; GeoGebra has amassed a user base in 190 countries and has been translated into over 70 languages (Furner, 2020). GeoGebra is an interactive mathematics application that covers geometry, algebra, statistics, and calculus, catering to students from primary school to university levels. It is accessible across various platforms, including desktop applications for Windows, MacOS, and Linux, tablet applications for Android, iPad, and Windows, and a web application based on HTML5 technology. GeoGebra aims to enrich students' understanding of mathematics, offering support for active and problem-oriented teaching, and facilitating mathematical experiments and discoveries both in the classroom and at home.

2. Literature Review

Multimedia learning instruction, defined as using presentations (words) and representations (figures), can enhance teaching and learning by combining verbal and visual representations of complex concepts (Mayer, 2009). However, despite this, the interdependence of technology and education has attracted students to the sciences in the past two decades. National Council of Teachers of Mathematics [NCTM] (2008) adds that spreadsheets, calculators, interactive presentation devices, computer algebra systems, interactive software, and applets all play a significant role in the long-term, successful learning and teaching of mathematics. Additionally, NCTM emphasizes that the use of technology in education is essential for teaching and learning mathematics, therefore all schools need the necessary technological infrastructure and equipment for the active use of educational technologies in mathematics education.

The Ministry of Education [MOE] has formulated various strategies to aid HEIs in fulfilling their mission through Information and Communications Technology [ICT]. Currently, the primary focus is on meeting the demand for affordable quality education from anywhere, which can only be accomplished through technology (MOE, 2023). In this context, Ethiopian HEIs are urged to take advantage of this opportunity to ensure the provision of quality education through all available avenues. Additionally, the MOE and other regional and global stakeholders have drafted several documents on the utilization of ICT in education. These include the Digital Skills Country Action Plan [DSCAP] 2021-2030; Higher Education Policy and Strategy (December 2020); Institutional ICT Policy for Higher Education in Ethiopia (December 2020); Digital Ethiopia 2025; Africa 2063 Digital Education Strategy; National ICT Strategic Plan for Higher Education (2021–2030); National ICT in Education Policy (2023); Digital Education Strategy and Implementation Plan (2023-2028); and National e-Learning Policy for Higher Education (2023). Moreover, the MOE expects the HEIs to explore and monitor emerging technologies and educational advancements, and to consider integrating them into the learning environment. They are also tasked with addressing e-learning requirements such as equipment procurement, software implementation, staff recruitment, training and research needs, staff workload, and technology developments (MOE, 2023). This underscores the significance of software implementation, training, research needs, and technology development in fostering effective teaching and learning practices at HEIs, particularly in the field of mathematics. Furthermore, the MOE's guiding principles policy for e-learning in Ethiopian higher institutions emphasizes empowering and supporting staff to pedagogically develop and deliver education supported by technology, ensuring its integration into the educational system (MOE, 2023, p. 5).

All these documents are designed to harness the potential of ICT to enhance educational delivery that is adaptable, effective, and inclusive for learners worldwide and all educational partners. For example, the National ICT in Education Policy (2023) establishes the legal framework for education and guides the implementation of education programs and initiatives. This policy includes provisions related to e-learning, such as the use of digital resources and technology in teaching. Additionally, the comprehensive plan, the digital education strategy, and the implementation plan (2023–2028) are aimed at realizing the national education plan and the ministry's objectives in achieving the country's digital transformation strategy and the AU's regional plan for the digitization of the education sector in line with the education millennium development target. Furthermore, the National e-Learning Policy for Higher Education (2023) shares the same framework as the National ICT in Education Policy (2023).

In Ethiopian higher institutions, mathematics teachers predominantly use traditional methods, such as the lecture method, along with the traditional paper-and-pencil approach. Although there has been a significant focus on science, technology, engineering, and mathematics [STEM] in Ethiopian universities since 2019, the training continues to heavily rely on traditional teaching methods and does not incorporate new technologies in mathematics courses. Some teachers argue that the core focus of mathematics teaching programs should be on equipping prospective teachers with strong subject matter knowledge. However, it has been noted that technological knowledge is not being sufficiently emphasized in Ethiopian teacher education, and traditional teaching methods are considered outdated for active learning in the 21st century.

Integrating technology into mathematics teaching and learning situations poses a significant challenge for educators due to a lack of teacher development in utilizing technology (Davidson et al., 2014). Additionally, teachers encounter obstacles such as insufficient infrastructure, and limited availability of computers, and other essential resources (De las Peñas & Bautista, 2011). Some educators also struggle with ICT skills and have a reluctance to embrace new teaching methods in mathematics. These factors hinder the successful integration of technology in the educational environment. Researchers emphasize the pivotal role of University Mathematics Teachers [UMTs] in establishing effective use of technology within their HEIs to benefit students. Therefore, this article aims to identify the barriers and challenges faced by UMTs in utilizing the DMS-GeoGebra to teach mathematics at Ethiopian Universities. To provide structure and clarity to the study, the article seeks to address the research question: What are the barriers to UMTs in using the mathematical software GeoGebra to teach mathematics at the tertiary level?

3. Method

3.1. Research Design

This study follows the post-positivist research paradigm, which integrates positivist and interpretivist perspectives to address both quantitative and qualitative data. The data were gathered through survey questionnaires and interviews with senior lecturers and above from the selected universities in Tigray region. The research design employed a mixed approach, specifically a convergent design, to collect both types of data (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.

3.2. Participants

The study included UMTs with an academic rank of lecturer or above from four Northern Ethiopian Universities - U_1, U_2, and U_3 in the department of mathematics. For the study, U_1, U_2 and U_3 were the main focus, while U_4 was chosen for the pilot study. A total of 96 UMTs participated: 52 from U_1, 28 from U_2, and 16 from U_3. A systematic sampling method was used for qualitative data collection and the mathematics department heads were selected using a purposive sampling method to ensure consistency and reliability of the instruments and collected data.

3.2.1. Sample and sampling technique

The statistical samples for this study consist of both male and female UMTs from the selected universities. The participants of this study were selected using stratified cluster sampling method. As outlined in the research design and methods section, 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 qualitative data collection, the researcher employed a simple random sampling method to choose mathematics teachers from the universities (U_1, U_2, and U_3) and all department heads for interviews. Recordings were also conducted based on their consent, and comprehensive notes were taken during the interviews.

3.2.2. Demographic information of participants

The first part of the questionnaire used in this study was to obtain demographic information such as highest level of academic qualification, current academic rank, work experience at university in years, and UMTs' experience in using GeoGebra of the main study of the participants (UMTs). Campbell and Stanley (1963) stated that experiments need replication and cross-validation at various times and conditions before the results hypothetically interpreted with confidence. Accordingly, the study comprises three groups taken from U_1 (n = 52), U_2 (n = 28), and U_3 (n = 16). As a total, 96 UMTs whose academic rank lecturer and above were participated in this study.

Table 1
Highest Level of Academic Qualification and Rank of UMTs

		University			*Total*
		U1	*U2*	*U3*	
UMTs' highest level of academic qualification completed					
Masters	N (%)	47 (57.3%)	20 (24.4%)	15 (18.3%)	82 (100.0%)
(MSc, MEd, MA)	% of Total	49.0%	20.8%	15.6%	85.4%
Ph.D.	N (%)	5 (35.7%)	8 (57.1%)	1 (7.1%)	14 (100.0%)
	% of Total	5.2%	8.3%	1.0%	14.6%
Total	N (%)	52 (54.1%)	28 (29.2%)	16 (16.7%)	96 (100.0%)
UMTs' academic rank					
Lecturer	N (%)	46 (66.7%)	20 (29.0%)	3 (4.3%)	69 (100.0%)
	% of Total	47.9%	20.8%	3.1%	71.9%
Assistant Professor	N (%)	4 (16.0%)	8 (32.0%)	13 (52.0%)	25 (100.0%)
	% of Total	4.2%	8.3%	13.5%	26.0%
Associate Professor	N (%)	2 (100.0%)	0	0	2 (100.0%)
	% of Total	2.1%	0.0%	0.0%	2.1%
Total	N (%)	52 (54.1%))	28 (29.2%)	16 (16.7%)	96 (100.0%)

As indicated in Table 1, majority of the UMTs who participated in the study 82(85.4%) have completed masters (MSc, MEd, MA) and the rest 14(14.6%) have Ph.D. as their highest level of academic qualification. Moreover, majority of the 69(71.9%) have academic rank lecture, and the rest 25 (26.0%) and 2 (2.1%) hold the academic ranks of assistant professor and associate professor, respectively.

Table 2
UMTs Work Experience at University

		University			*Total*
		U1	*U2*	*U3*	
Less than 10	N (%)	14 (56.0%)	4 (16.0%)	7 (28.0%)	25 (100.0%)
	% of Total	14.6%	4.2%	7.3%	26.03%
10-20	N (%)	36 (53.7%)	22 (32.8%)	9 (13.4%)	67 (100.0%)
	% of Total	37.5%	22.9%	9.4%	69.8%
20-30	N (%)	0	1 (100.0%)	0	1 (100.0%)
	% of Total	0.0%	1.0%	0.0%	1.04%
above 30	N (%)	2 (66.7%)	1 (33.3%)	0	3 (100.0%)
	% of Total	2.1%	1.0%	0.0%	3.13%
Total	N (%)	52 (54.1%)	28 (29.2%)	16 (16.7%)	96 (100.0%)

As indicated in Table 2, majority of the participants 67(69.8%) have 10-20 years of teaching work experience at university and the rest 25(26.03%), 1(1.04%), and 3(3.13%) have less than ten years, 20-30 years, and above 30 years of teaching work experience at university respectively.

Table 3
UMTs Experience in Using GeoGebra to Teach Matrices and Calculus-I

		University			*Total*
		U1	*U2*	*U3*	
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 3, majority of the UMTs 79(82.3%) in the three Northern Ethiopian cluster universities have no experience in using the DMS-GeoGebra to teach mathematics contents. The rest 17(17.7%) have an experience in using GeoGebra for teaching.

3.3. Instruments and Procedures

To identify the barriers that prevent UMTs from using the mathematical software GeoGebra, the researchers conducted a questionnaire survey and structured and unstructured interviews with both the UMTs participating in the study and the head of the mathematics department. The materials used in the study included a personal computer (PC laptop), a 5-point Likert scale survey questionnaire designed to identify barriers to UMTs using the software, structured and unstructured interviews, the mathematical software(GeoGebra), and the statistical software SPSS for data analysis. Multiple data collection instruments were used to accommodate the nature of the variables in this study.

3.3.1. Administration of the Questionnaire Survey

The researchers conducted an online survey using a Google Form questionnaire to collect data from lecturers and senior academic staff at three universities in Northern Ethiopia (U1, U2, and U3). The purpose of the survey was to identify the obstacles encountered by these staff members when utilizing the mathematical software GeoGebra in their teaching practices. The survey comprised seven questions, and the responses were examined using Cronbach's alpha to gauge internal consistency. Moreover, SPSS-20 was employed to calculate frequency, percentages, as well as measures of central tendency and variation. The results of the survey can be found in Table 8 and Table 10, subsection 4.2, where descriptive statistics are presented.

3.3.2. UMTs' interviews

A total of eight participants comprised of five UMTs and three heads of departments were interviewed to discuss the challenges and obstacles they encountered when using the DMS-GeoGebra for teaching mathematics at their respective institutions. The participants were chosen using systematic and purposive sampling methods. The interviews took the form of question and answer sessions, during which the interviewer used a smartphone to record the participants' responses. Subsequently, the recorded audio was transcribed into text as indicated in the supplementary material.

3.3.3. Validity and reliability of the instruments

During a pilot study, we evaluated the reliability and validity of our research instruments on a pilot group of UMTs with an academic rank of lecturer and above at U4. This allowed us to identify 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. We were also used face validity, construct validity, and content validity to assess the instruments. Our colleagues assisted in checking face and content validity, while we employed theoretical background and literature review to address construct validity.

To ensure consistent results across items, we measured the internal consistency reliability of the quantitative instruments using the Cronbach alpha coefficient. Specifically, we computed Cronbach's alpha to check the reliability of the ten items that were summarized to create the UMTs' barriers to using the software score. An item with a Cronbach's alpha value equal to or greater than 0.5 is considered acceptable, indicating reasonable reliability. We also computed inter-item correlation to examine any deficient items. It is worth noting that the pilot study showed the internal consistency reliability of the UMTs' barriers in using GeoGebra was .598, as presented in Table 4.

Table 4
Reliability Statistics of the Instruments of the variable

Variables	*No. of Items*	*Cronbach's Alpha*	*Cronbach's Alpha After Items Deleted*	*Updated No. of Items*
Barriers to use GeoGebra	10	.598	.798 (#6, #7 and #9)	7 (To increase reliability and the three items have a negative inter-item correlation)

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.

To assess the barriers for UMTs to use the GeoGebra DMS, the researchers analyzed ten items and developed a scale. They used Cronbach's alpha and inter-item correlation to ensure the consistency of the items. The pilot study revealed an internal consistency reliability of 0.798 for the Barriers to use GeoGebra scale after excluding three items (#6, #7, and #9) due to their low and negative inter-item correlation with the whole scale. This exclusion resulted in an increase in internal consistency reliability from 0.598 to 0.798. As a result, for the actual study, the barriers to UMTs to use GeoGebra were assessed using a seven-item scale.

3.4. Data Organization and Analyses

This research is based on a combination of quantitative and qualitative data collected from mathematics lecturers and higher-ranking academics at Ethiopian universities during the 2023/2024 academic year. 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 $p \leq .05$ using the least significance difference to examine differences among mathematics teachers in terms of their obstacles to using the software GeoGebra in teaching mathematics at the tertiary level. The barriers to implementing the DMS-GeoGebra in teaching mathematics at Ethiopian Higher Education Institutions [EHEIs] (specifically U_1, U_2, and U_3) were classified based on the criteria as outlined in Table 5.

Table 5
Criteria for Categorizing the Barriers to UMTs' to use GeoGebra

Level	*<2.6*	*2.6-3.60*	*>3.60*
Categories	Low	Moderate	High

Again, the qualitative data obtained from the interview responses were transcribed into question and answer dialogues. These excerpts were presented to support the results of quantitative data analysis and discussions.

3.5. Ethical Considerations

This research study commenced with the acquisition of ethical clearance from the Department Graduate Councils, the College of Natural and Computational Sciences, and a letter of ethical clearance from the College of Health Sciences, Institutional Review Board, and expedited approval was received on 25/03/2024, with Notification of Protocol Approval MU-IRB 2191/2024 at Mekelle University. These documents serve as a framework for the research, guaranteeing compliance with fundamental research regulations, integrity, and ethical conduct involving human subjects. This encompasses ensuring participant anonymity, obtaining participant consent, and upholding data confidentiality. Informed consent was secured, and codes were utilized instead of names. Data was securely stored on computers with robust passwords and in physically secure locations to safeguard participant anonymity and data confidentiality.

4. Results

4.1. Normality and Homogeneity Variance Tests of the Quantitative Data

Table 6 shows that the descriptive statistics of the variable; barriers of UMTs to use GeoGebra in their teaching practice at tertiary level.

Table 6
Descriptive Statistics

Variable	*N*	*Minimum*	*Maximum*	*Mean*	*SD*	*Variance*	*Skewness*	
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Statistic*		*Statistic*	*SE*
Barriers	96	1.57	5.00	3.66	.72	.516	−.306	.246

As it could be seen in Table 6 above, the skewness of the scale variable was computed to determine the distribution of the data. According to Cohen (1988) if the skewness is less than plus or minus one (± 1.0), which is the rule of thumb of approximately normal distribution. Hence, the scale items of the variable of this study is at least approximately normal, which is one of the assumptions for using parametric tests. Using this thump rule, the variable was approximately normal as $-.1 < -.306 < 1$. Thus, we can use parametric tests to analyze the data during the between and within group comparison.

Table 7
Levene's Test (Homogeneity of Variance) of the Variables

Variables	*Levene Statistic*	*df1*	*df2*	*p*
Barriers to UMTs to Use GeoGebra	.128	2	93	.880

As indicated in Table 7, it can be seen that the Homogeneity of variance for the variable barriers to UMTs to Use GeoGebra in teaching mathematics holds, as the Levene's test of equality of variances met $F(2,93) = .128$, $p = .880 > .05$ indicates that there is no a significant difference of variance with respect to the barriers of the UMTs to use the mathematical software-GeoGebra.

4.2. Analysis and Interpretation of the Quantitative Data

Before answering the research question, first the researchers seek to answer whether there is a difference between groups (U_1, U_2, and U_3) on the variable scale items: barriers to use GeoGebra in teaching mathematics of the UMTs in the three universities whose academic rank is lecturer and above. Thus, for the purpose of identifying the difference between the groups at the three universities, descriptive statistics and one-way ANOVA were computed.

Table 8
Descriptive Statistics of the Three Groups in the Variables of the Study

Variables		*N*	*Mean*	*SD*	*SE*	*95% Confidence Interval for Mean*	
						Lower Bound	*Upper Bound*
Barriers	U_1	52	3.65	.72	.09	3.45	3.85
	U_2	28	3.67	.72	.14	3.39	3.95
	U_3	16	3.60	.75	.19	3.20	4.00
	Total	96	3.65	.72	.07	3.50	3.79

The Mean and standard deviation were performed to summarize and describe the data sets obtained from the UMTs whose academic rank is Lecturer and above for the variable scale items of UMTs' barriers to use the software to teach mathematics at their respective university (U_1, U_2, and U_3). Table 8 shows that there is no significant variation of mean score were detected (see also Table 9) among the three groups of UMTs with respect to their barriers/challenges to UMTs to use the software in their teaching practices (*Mean* = 3.64, 3.67, and 3.60 with SD = .72, .72, and .76, respectively) for the three groups of UMTs at U_1, U_2, and U_3, respectively. Therefore, at the beginning of the study the three groups were considered nearly similar with respect to the variable scales; barriers to use the software in teaching mathematics. However, these results do not enable to generalize with certain level of confidence and significance. Hence, generalizing the results was detained until the appropriate inferential statistics was performed as indicated in Table 9.

Table 9
One-way Analysis of Variance results of the three UMTs' Group

Variables		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
Barriers	Between Groups	.058	2	.029	.055	.947
	Within Groups	48.961	93	.526		
	Total	49.018	95			

The between subjects one-way Analysis of Variance (ANOVA) was conducted to see the UMTs group statistical difference with respect to their barriers to use GeoGebra in teaching mathematics. The statistical assumptions for the ANOVA model had been checked before it was used for comparing the group and these assumptions were met (see tables 6 and 7 above). As indicated in Table 9, the result of the study shows that there was statistically non-significant between UMTs group difference on their barriers to use the software in teaching mathematics ($F(2,93) = .055$, $p = .947 > .05$).

The research question of this study was 'what are the barriers to UMTs in using GeoGebra in teaching mathematics?' or the purpose of this study is to identify the barriers to UMTs to use GeoGebra in their teaching practices. To this end, a questionnaire five point Likert-scale surveys were distributed to the UMTs whose academic rank are lecturer and above in the Northern Ethiopian cluster universities U_1, U_2, and U_3.

The UMTs' barriers to use GeoGebra in their teaching practice at university to teach mathematics were elicited by a questionnaire survey consisting of seven (7) items to identify the barriers for UMTs to use the DMS in their teaching and learning practices at their respective universities. The questionnaire was distributed to all mathematics teachers whose academic rank is lecturer and above at U_1, U_2, and U_3 of the Northern Ethiopian cluster universities. The results of the analysis of the responses reflect that UMTs' challenges to use GeoGebra in their teaching practices (with an overall mean of M = 3.65) as shown in Table 10.

Table 10
Percentages and Means of Barriers to UMTs in Using GeoGebra to Teach Mathematics

Items	*SD*	*DA*	*N*	*A*	*SA*	*Mean*	*SD*
Access to and support in using technology.	5 (5.21%)	18 (18.75%)	23 (23.96%)	31 (32.29%)	19 (19.79%)	3.43 Moderate *	1.16
Teachers' perceptions, beliefs, and skills on how GeoGebra should be used in teaching and learning.	7 (7.29%)	10 (10.42%)	28 (29.17%)	30 (31.25%)	21 (21.88%)	3.50 Moderate *	1.16
Lack of funding and inadequate support to staff.	3 (3.13%)	11 (11.46%)	17 (17.71%)	34 (35.42%)	31 (32.29%)	3.82 High*	1.11
Lack of Training and awareness in Mathematical Software.	1 (1.04%)	4 (4.17%)	18 (18.75%)	36 (37.50%)	37 (38.54%)	4.08 High*	.91
Curriculum of Mathematics.	5 (5.21%)	6 (6.25%)	19 (19.79%)	28 (29.79%)	38 (39.58%)	3.92 High*	1.15
Reluctant to change	13 (13.54%)	19 (19.79%)	37 (38.54%)	19 (19.79%)	8 (8.33%)	2.90 Moderate*	1.13
Lack of adequate infrastructure	2 (2.08%)	11 (11.46%)	20 (20.83%)	26 (27.08%)	37 (38.54%)	3.89 High*	1.11
Over all	36 (5.36%)	79 (11.76%)	162 (24.11%)	204 (30.36%)	191 (28.42&)	3.65	.52

Note. * indicates the decision based on the average mean = 3.65; N = 96; SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree. Decision – weighted average = 25.54/7 = 3.65.

As indicated in Table 10 and using the criteria categorization, the data analysis shows that majority of the respondents (UMTs) appeared highly to agreed that the lack of funding and inadequate support to staff (*Mean* = 3.82, *SD* = 1.2) is their barrier to use the DMS-GeoGebra. Also, they sensed highly that the lack of training and awareness in the Mathematical Software (*Mean* = 4.08, *SD* = .91). They agreed also highly that the curriculum of mathematics (*Mean* = 3.92, *SD* = 1.15) challenged them to use GeoGebra in their teaching practice of mathematics at university, and they highly agreed that the lack of adequate infrastructure (*Mean* = 3.89, *SD* = 1.11) challenged them to use the software. On the other hand, Majority of the participants (UMTs); the access and support in using technology (*Mean* = 3.43, *SD* = 1.16), UMTs' perceptions, beliefs, and skills on how GeoGebra can be used in teaching and learning practice (*Mean* = 3.50, *SD* = 1.16), and UMTs reluctance to change (*Mean* = 2.90, *SD* = 1.13), had moderately challenge to them to use the DMS-GeoGebra in teaching the contents of mathematics in general at university.

The researchers again check whether there are differences among the UMTs with respect to their academic rank and work experience regarding the barriers faced to use GeoGebra at the HEIs.

Table 11
Descriptive Statistics of UMTs Barriers with respect to their Academic Rank

Variables	*N*	*Mean*	*SD*	*SE*	*95% Confidence Interval for Mean*	
					Lower Bound	*Upper Bound*
UMTs' Academic Rank						
Lecturer	69	3.66	.70	.084	3.49	3.83
Assistant Professor	25	3.71	.69	.14	3.43	3.99
Associate Professor	2	2.36	1.11	.79	−7.63	12.34
Total	96	3.65	.72	.073	3.50	3.79
Work Experience at University in Years						
Less than 10	25	3.72	.71	.14	3.42	4.01
10-20	67	3.62	.68	.08	3.46	3.79
20-30	1	4.00	.	.	.	.
above 30	3	3.48	1.75	1.01	−.86	7.81
Total	96	3.65	.72	.073	3.50	3.79

The results presented in Table 11 shows that there is a variation in the mean scores among the UMTs with respect to their academic rank (Associate Professor) and have above 30 years work experience at University regarding their barriers to use GeoGebra. Conversely, Table 11 reveals that there is insignificant variations in mean scores among the UMTs with respect to their academic ranks (Lecturer and Assistant Professor); and work experience at University in years regarding their barriers to use GeoGebra. However, these results should not be generalized with a high level of confidence or significance. To this end, the between subjects one-way analysis of variance [ANOVA] was conducted to compare UMTs' barriers to use the software with respect to their academic rank and work experience; as a result a significant differences were found among the UMTs' in terms of their barriers in using GeoGebra due to their academic rank difference ($F(2,93) = 3.624$, $p = .033 < .05$); but, insignificant difference with respect to their work experience ($F(2,93) = .243$, $p = .866 > .05$).

Moreover, to identify which UMTs' Academic rank showed differences with respect to their barriers to use the software in teaching mathematics at the HEIs, a post hoc analysis using Fisher's Least Significant Difference [LSD] was conducted, as presented in Table 12.

Table 12
Post Hoc LSD Analysis Comparisons of UMTs' Barriers with respect to their Academic Rank

Dependent Variable	*(I) Academic rank*	*(J) Academic rank*	*Mean Difference (I-J)*	*SE*	*p*	*95% Confidence Interval*	
						Lower Bound	*Upper Bound*
UMTs' Barriers to Use GeoGebra	Lecturer	Assistant Professor	−.054	.16	.743	−.38	.27
		Associate Professor	1.30*	.50	.011	.31	2.30
	Assistant Professor	Associate Professor	1.36*	.51	.010	.34	2.38

Note. *:The mean difference is significant at the .05 level.

The multiple comparisons presented in Table 12 indicate that there is a significant difference among UMTs with respect to their academic rank regarding to the challenges faced them in using the DMS-GeoGebra in teaching mathematics at HEIs whose academic rank is Lecturer and Associate Professor, as well as Assistant Professor and Associate Professor ($p < .05$). The results further showed that UMTs hold Associate Professor academic rank more challenged an average of 1.30 mean higher than those hold Lecturer academic rank and mean 1.36 higher than those hold Assistant Professor academic rank. However, the mean difference between the UMTs holding academic rank Lecturer was .054 average mean lower than those hold Assistant Professor; and insignificant ($p = .743 > .05$).

4.3. UMTs' Interview Data Analysis

The interviewees discussed the challenges they faced when teaching mathematics using GeoGebra. They identified the most challenging aspects as the students' experience with the software, the availability of computers, and the shortage of resource materials. However, the software is easily accessible and has no more challenges for teaching matrices and calculus concepts. The most challenging aspect was creating more matrices and inserting two or more matrices simultaneously. Moreover, the interviewees also mentioned that they had no background in the software and had no information about its use before the intervention training. They also faced challenges in representing mathematical concepts graphically, such as 3D graphics. The interviewees also noted that the institution and department did not encourage such teaching and learning processes due to damaged infrastructure and a lack of computers and laboratories in universities.

The interviewees also noted that not all courses integrate software into their teaching and learning. They believe that policy and curriculum should be considered when preparing curriculums, but integrating GeoGebra with other courses or software like Python, MatLab, and Mathematica would make it more attractive. Again, the interviewees also mentioned that the reasons for not using GeoGebra include a lack of internet access, a lack of awareness about technological advancements, and a lack of training in the software. They concluded that the main challenges faced by teachers and students in using GeoGebra are students' experience with the software, awareness, exposure, and training.

5. Discussion

The researchers of this study discussed the challenges faced by UMTs in teaching mathematics in the EHEIs using GeoGebra and found that the most challenging aspects were: lack of access and support in using technology, the Mathematics curriculum itself, UMTs' resistance to change pedagogical concerns, lack of teachers' professional development, perceptions, beliefs, and skills on the DMS-GeoGebra, financial amount and resources required for those technologies, lack of funding and inadequate staff support; teachers' and students' experience with the software; the availability of computers and laboratories; lack of adequate infrastructure; the shortage of resource materials due to damaged infrastructure and finance; lack of awareness among mathematics teachers that mathematics can be taught using mathematical software; lack of awareness about technological advancements; and lack of training and exposure in the software.

Despite its benefits, the integration of GeoGebra is not without challenges. For instance, some educators may struggle with effectively incorporating the software into their teaching practices, which can hinder its potential impact (Kllogjeri & Kllogjeri, 2024). To this end, the integration of GeoGebra into teaching practices by UMTs faces several challenges that hinder its effective use. These challenges stem from both infrastructural limitations and pedagogical concerns, which can significantly impact the learning experience (Kllogjeri & Kllogjeri, 2024). Additionally, while engagement may increase, motivation levels can remain unchanged (Ardina & Boholano, 2024).

Several scholars have also reported gaps in the use of technologies, specifically mathematical software, in teaching in the classroom (Miller & Glover, 2007; Mokotijo & Mokhele, 2021; Tay et al., 2012). Specifically, Mokotijo and Mokhele (2021) explores the difficulties faced when incorporating GeoGebra into the high school mathematics curriculum and highlighted the issues are related to teacher training, resource limitations, and the need for ongoing support to effectively integrate GeoGebra into the classroom. Moreover, Tay et al. (2012) also reported that the frequency of ICT use is significantly lower in mathematics lessons and mathematics teachers primarily adopted the learning from ICT pedagogy with occasional learning. Effective interactive teaching requires continuing professional development and specific personal coaching with a consideration of interactive techniques and pedagogy (Miller & Glover, 2007). The integration of technologies in the classroom of Ethiopian higher institutions has been slower than expected due to lack of teachers' professional development, perceptions, beliefs, and skills on it (Agyei & Voogt, 2010); shortage of computers in school restricts mathematics teachers skills to use technologies in their teaching practice (De Witte & Rogge, 2014); financial amount and resources required for those technologies (Mokotijo & Mokhele, 2021). Factors that may create barriers to teachers' use of technology include their perceptions of the technological knowledge, confidence in handling unexpected problems, and their beliefs about the time and money costs for themselves and their students (Pierce & Ball, 2009).

The ability of teachers to effectively use ICT influences the quality of teaching mathematics, which is particularly important as many students find mathematics to be abstract and challenging (Bayaga et al., 2019; Mokotjo & Mokhele-Makgalwa, 2021). Teachers' use of technology is influenced by their perceptions of students' attitudes toward mathematics; they must believe that using technology will enhance students' motivation and interest (Mumtaz, 2000). Additionally, teachers are more likely to use computers in math classrooms if they believe it will boost students' motivation, enjoyment, and confidence (Forgasz, 2006).

Instructors' attitudes and perceptions during technology integration significantly affect their teaching practices and their selection of effective learning opportunities for students (Cuban et al., 2001). Recognizing the pivotal role of teachers, the National Council of Teachers of Mathematics (NCTM, 2008) identifies them as one of the six essential elements supporting the successful deployment of new technologies in mathematics education. Therefore, understanding teachers' opinions and ideas about new computer-based programs from various perspectives can help facilitate the technology integration process and overcome its challenges (Belgheis & Kamaludeen, 2018).

Several important factors play a role in shaping a teacher's approach to teaching and learning mathematics in the classroom. One of these crucial factors is the teacher's mental schemas, which encompass a set of beliefs about teaching and learning mathematics (Ernest, 1989a) and their beliefs regarding the use of technology. The nature of mathematics as a concept, the nature of math instruction as a model, and the nature of the arithmetic learning process as a model are the three core ideas that Ernest (1989a) finds among mathematics teachers. He presents a model that elucidates how these beliefs influence behavior. This model encompasses the dynamic interactions between theories about the nature of mathematics, theories about how mathematics is learned and applied, and theories about how mathematics is taught. Ernest (1989a) asserts that the practices of mathematics instructors are greatly influenced by their beliefs and ideas.

Individuals' beliefs, attitudes, and emotions significantly influence their interests and responses to mathematics and its application in their lives (Saralar-Aras, 2022). Therefore, it is unsurprising that instructors' perspectives play a crucial role in their teaching methods (Nespor, 1987). The beliefs of mathematics teachers and their methods of teaching are directly related, according to a number of studies (Cross, 2009; Ernest, 1989b; Stipek et al., 2001; Zakaria & Maat, 2012). For example, Cross (2009) found a distinct correlation between math teachers' belief systems and their teaching methods. Recent studies also support these findings, emphasizing the reciprocal relationship between teachers' beliefs and practices (Yang et al., 2020; Yurekli et al., 2020). Furthermore, the way that technology is incorporated into classes is influenced by the beliefs of teachers (Saralar-Aras, 2022). These beliefs encompass the personal meaning of math, professional identities, self-efficacy (Zbiek & Hollebrands, 2008), and values (Akyıldız et al., 2021; Clarkson et al., 2019).

In their study, Daniel and Bärbel (2022) emphasized the importance of teachers' self-efficacy views, epistemological beliefs, and beliefs about teaching using technology for effectively integrating technology into mathematics instruction. Numerous studies have demonstrated that the incorporation of technology in the classroom can significantly improve students' learning outcomes. By allowing for the dynamic integration of various representations and supporting more constructivist teaching techniques, technology has the potential to enhance learning (Ball et al., 2018; Bray & Tangney, 2017; Drijvers, 2019; Drijvers et al., 2016; Hillmayr et al., 2020). However, realizing the full benefits of technology and minimizing its challenges requires rigorous pedagogical application; technology cannot reach its full potential on its own (Jankvist et al., 2019). Despite being widely accepted in some nations, technology is often underutilized, and teachers may fail to capitalize on its potential as suggested by research and policy (Bretscher, 2014, p. 43). Therefore, understanding the factors associated with the effective use of technology in the classroom is crucial (Clark-Wilson et al., 2014; Drijvers, 2019). Among these factors, teachers' beliefs play a significant role (Fives & Buehl, 2012). Teachers' beliefs need to shape and guide their actions and intentions. According to Tondeur et al. (2017) three aspects of teacher beliefs are particularly relevant for teaching with technology, one of which is the belief about teaching with technology. Previous research has delved into the reasons and mechanisms underlying the presence of these beliefs in the unique belief systems of teachers (e.g., Duncan, 2010; Erens & Eichler, 2015).

Teachers' perspectives on the role of technology in education, known as "beliefs about the role of technology in teaching and learning," encompass their attitudes toward integrating technology into the classroom (Goos & Bennison, 2008, p. 105). These beliefs encompass their perceptions of the advantages and disadvantages of utilizing technology in teaching (Pierce & Ball, 2009). Studies have shown that teachers' utilization of technology is influenced by these beliefs (e.g., Duncan, 2010; Erens & Eichler, 2015; Hennessy et al., 2005). For instance, Hennessy et al. (2005) identified that teachers' adoption of technology was associated with their recognition of its educational value and belief in its potential to bring about transformative changes (p. 185), as revealed in focus group interviews with teachers. However, there is limited research on the various sub-dimensions of teacher beliefs about technology, aside from the fundamental understanding that positive beliefs regarding teaching with technology have a positive impact on teaching mathematics using technology.

Goos and Bennison (2008) found that teachers' beliefs about technology's role in facilitating discovery learning were significantly more closely associated with their self-reported use of technology, compared to their beliefs about how technology influences students' attitudes. According to Erens and Eichler (2015) these findings underscore the importance of exploring different connections further.

The expertise and capabilities of teachers are vital internal factors to consider, in addition to the instructor's viewpoint, content assessment, and technological proficiency (Muhazir & Retnawati, 2020); and their skills in using technology. As per the MOE's Institutional E-Learning Policy Guideline for HEIs in Ethiopia (2023), e-learning initiatives in HEIs are poised to revolutionize education in EHEIs through the integration of technologies, institutional capacity enhancement, and development of faculty and student capacities. This will be followed by innovative approaches to address emerging needs and extend the utilization of technology. As a result, educational institutions must shape and strategize their digital capabilities while considering the requirements of students, teachers, technology providers, course designers, and e-learning program administrators. This should encompass the technological prerequisites and the interventions they intend to implement.

The majority of HEIs have not progressed significantly beyond the utilization of PowerPoint slides and online lecture platforms such as Zoom and Google Meet for course delivery. The MOE (2023) has pointed out that a significant challenge is the technological skill gap among instructors. The national policy also highlights intellectual property, copyrights, and the teacher skill gap as its main areas of policy concern.

The Ethiopian Federal Ministry of Education considers teachers' skills as one of the focus areas in its e-learning policy for higher education (MOE, 2023). It has been noted that the quality of e-learning programs depends on the quality and skills of the major stakeholders who are developing the contents, facilitating the learning, and conducting student support and assessment, in addition to the availability of e-learning tools and technology. Moreover, the ministry believes that this can only be achieved when there are skilled and motivated academic staffs. It also recommends that HEIs ensure that staffs have the minimum required basic computer literacy skills to interact with the technology used in e-learning, the capacity to measure the success of the teaching, learning, and evaluation processes and interpret learning analytics. Furthermore, instructors, trainers, and content developers should be well-trained and equipped with the latest knowledge and skills in using technology tools to create materials to support e-learning. Finally, for staffs that don't have the necessary skills, capacity building should be provided as per their demand (MOE, 2023, p. 9).

Research suggests that teachers' technology-use strategies and competencies have an impact on how technology is implemented in math classes (Ailincai & Gabillon, 2018; Farjon et al., 2019). Regarding TPACK, teachers are believed to possess outstanding technical abilities. Technology adoption in education can benefit from teachers' acquisition of technology-using skills through outreach and training programs that enhance their professionalism and introduce learning websites, applications, videos, and other technologies that can be utilized in mathematics instruction (Sang et al., 2011).

Teachers need to possess the necessary technological skills and expertise to employ technology in the classroom. Teachers also face the issue of maintaining a positive attitude and evaluating technology usage in the classroom while selecting the appropriate materials or content. Furthermore, because the majority of TPACK math teachers are less experienced than other subject matter experts, like science, ICT, and homeroom teachers, TPACK, which is owned by math teachers, needs to be taken into consideration and improved through training (Farjon et al., 2019).

The presence of comprehensive technological tools and appropriate mathematics learning materials does not guarantee the smooth integration of technology into mathematics instruction in the classroom (Muhazir & Retnawati, 2020). One significant barrier to utilizing technology in the classroom is the proficiency of teachers in its use. Public perception also supports the notion that computers are valuable curriculum tools and a transformative classroom approach that can help students achieve significant learning gains and a better understanding of mathematical concepts (Goddard, 2002). Furthermore, Muhazir and Retnawati (2020) identified three barriers that hinder mathematics teachers from using technology in the classroom: (1) inadequately suitable math curriculum materials for technology; (2) insufficient facilities, infrastructure, and support from the school system; and (3) teachers' skills, lack of information, and inadequate training in using technology for math instruction.

The challenges to UMTs' in using GeoGebra also exist due their pedagogical challenges and reluctant to change (unwillingness to use technology), awareness on the DMS-GeoGebra, students' experience with the software, lack of training, exposure, the mathematics curriculum itself, and UMTs' resistance to change. Nelkon and Parker (1995) explain that according to Newton's first law of motion, an object will stay at rest or continue moving at a constant velocity unless it is acted upon by an external force. This inertia has direct implications for the reluctant to change or unwillingness to use the software in teaching and learning mathematics in EHEIs. These findings are also in consistent with the study (De Araujo et al., 2023; Mokotjo & Mokhele, 2021). De Araujo et al. (2023) argued that educators may be hesitant to adopt new technologies, preferring traditional teaching methods due to their resistance to change and the need for public policies that encourage the integration of technology in mathematics education, lack of supportive Policies and Curriculums. Moreover, Limited Access to Technology (Mokotjo & Mokhele, 2021) and Insufficient Training

De Araujo et al. (2023) are the other barriers to teachers in integrating GeoGebra in their teaching practices. Mokotjo and Mokhele (2021) stated that inadequate access to ICT resources, with instances of vandalism leading to the loss of essential equipment like data projectors; and De Araujo et al. (2023) argued that lack of the necessary training to effectively utilize GeoGebra, resulting in underutilization of its capabilities.

Regrettably, many teachers and university professors lack the necessary expertise to effectively utilize mathematical software and technical know-how to use it. While they are adept at using basic office software like word processing, spreadsheets, and email, they are hesitant to explore more advanced programs, expressing concerns about their potential impact on the teaching and learning process (Ochkov & Bogomolova, 2015). University teachers must be proficient in a wide range of computing tools, spanning from information technologies to computer software and hardware engineering. Mastery of these skills will enrich classroom instruction and facilitate the monitoring of experimental and laboratory equipment. Despite these benefits, the utilization of mathematical software in the teaching and learning of mathematics in Ethiopia remains limited, partly because some teachers are unaware of its existence and practical applications.

Moreover, the lack of adequate infrastructure and finance are also challenging to the UMTs to use GeoGebra in their teaching mathematics. Benning et al. (2023) argued that there are some teachers which hesitate to fully integrate GeoGebra into their teaching due to external constraints, highlighting the need for supportive infrastructures in educational settings which is in agreement with the findings of (Kllogjeri & Kllogjeri, 2024). Moreover, Wassie and Zergaw (2019) also stated that the common barriers to use GeoGebra in teachers teaching practices include limited access to resources, insufficient training, and challenges related to the software's complexity, particularly for those without prior programming experience. In line with the e-learning policy for higher education, HEIs are tasked with selecting suitable software to be installed on servers, in addition to the Learning Management System [LMS]. HEIs are strictly prohibited from using pirated software. The policy encourages the use of user-friendly LMS and open-source tools to minimize students' reliance on pirated proprietary software, allowing for constant online interaction between instructors and students for self-paced learning. HEIs must also ensure that all digital teaching materials are readily available to students on the e-learning platform. It's worth noting that effective use of computers for teaching requires reliable electricity and telecommunication services, which are presently insufficient in Ethiopia.

Furthermore, as stated by Ughamadu (2006), insufficient funds can pose significant challenges in implementing innovations. Without adequate funding for necessary materials, equipment, and facilities, it becomes difficult to implement innovations effectively and efficiently. In the context of using computers and mathematical software for teaching and learning, it is crucial to have a sufficient number of computers or laptops, ideally providing one per teacher and student. Finally, as the challenges faced by UMTs in using GeoGebra in their teaching practices are highly significant they are struggling to effectively incorporate the software into their mathematics teaching practices, which hinder its potential impact (Kllogjeri & Kllogjeri, 2024).

6. Conclusion

After discussing the challenges faced by University Mathematics Teachers (UMTs) in teaching mathematics in Ethiopian Higher Education Institutions (EHEIs) using GeoGebra, the researchers concluded that several key factors present significant obstacles. The most challenging aspects include both teachers' and students' limited experience with the software, as well as the inadequate availability of computers and laboratory facilities. Additionally, a shortage of resource materials—often due to damaged infrastructure and financial constraints—further hampers effective implementation. There is also a notable lack of awareness among mathematics teachers and students regarding the potential of mathematical software like GeoGebra in teaching, as well as limited understanding of broader technological advancements. Finally, the absence of adequate training in the use of the software contributes to the difficulty in integrating GeoGebra into mathematics education.

7. Recommendations and Implications

GeoGebra offers dynamic graphical representations of abstract mathematical concepts, making them more accessible and easier to visualize, particularly through its 3D visualization and animation features. This software enhances efficiency, saves time, and improves conceptual understanding, making it especially suitable for students at all grade levels, with particular emphasis on undergraduate and science-shared students in EHEIs. To ensure effective use of GeoGebra, UMTs should begin by introducing the software to students, explaining its features and benefits, and incorporating interactive demonstrations during lectures. They should also encourage students to engage in problem-solving activities using GeoGebra to explore and analyze mathematical problems.

Furthermore, it is important to allocate class time for students to work independently or in small groups with the software, providing necessary guidance as they complete tasks or projects aligned with course objectives. Incorporating real-world applications of mathematics into GeoGebra-based activities can further enhance student motivation and engagement. To support this integration, universities should develop a curriculum designed to be taught using GeoGebra, leveraging its capabilities in geometry, algebra, calculus, and other mathematical areas.

To teach effectively with GeoGebra in EHEIs, UMTs must invest time in learning its features, regularly attend training programs, workshops, and online tutorials, and identify curriculum topics that can be enriched with GeoGebra applications. They should design engaging lessons that incorporate the software and seek collaboration and support from colleagues and fellow mathematics educators. Finally, policymakers and curriculum designers should recognize the value of GeoGebra in the teaching and learning process, and prioritize ongoing training and workshops to equip UMTs and institutions across Ethiopia with the skills and resources necessary to integrate this dynamic mathematical software into their instruction.

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