Development of an Online Training Program for Mathematics Teachers in Using GeoGebra

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Abstract: *For years, the Institute for the Promotion of Teaching Science and Technology (IPST), serving as the GeoGebra Center of Thailand, has been providing onsite training to teachers on using GeoGebra for mathematics instruction. However, due to the COVID-19 pandemic, the traditional onsite training has been replaced with an online alternative. The main objectives of this research were: (1) to develop an online training program for teachers focused on using GeoGebra for mathematics teaching and (2) to explore the satisfaction level of teachers who participated in the developed online training program. The study included 108 mathematics teachers as subjects, all of whom took part in the developed online training. The findings indicate that, overall, the participating teachers expressed a high level of satisfaction with the online training in using GeoGebra for mathematics instruction.*

1. Introduction

GeoGebra, as a dynamic software, serves as a valuable resource for supporting mathematics instruction [1]. Its capabilities make it a powerful tool in the classroom, enabling the creation of dynamic visualizations and interactive demonstrations that effectively illustrate abstract mathematical concepts [2]. Moreover, GeoGebra has proven to be highly effective in facilitating students' learning experiences. By enhancing their understanding of mathematical concepts, promoting active engagement, and fostering motivation [3], it empowers students in their pursuit of learning mathematics.

For years, the Institute for the Promotion of Teaching Science and Technology (IPST), operating under the Ministry of Education in Thailand, has served as the GeoGebra Center of the country. It offered onsite training to educators, emphasizing core tools (geometry, algebra, statistics) and practical classroom use. Unfortunately, the traditional onsite training had to be discontinued due to the COVID-19 pandemic, despite the continued need for mathematics teachers to acquire proficiency in using GeoGebra. As a result, IPST was compelled to shift its focus and develop an online training program to meet the demand for utilizing GeoGebra for mathematics instruction. This adaptation allowed teachers to continue their professional development in GeoGebra while ensuring safety and accessibility during these challenging times.

In 2022, IPST created an online training program tailored to teachers seeking to employ GeoGebra in mathematics instruction. This online program took inspiration from IPST's prior successful onsite training. The primary objectives of the new online training program remained similar to those of the onsite program, aiming to equip teachers with effective strategies for utilizing GeoGebra in mathematics instruction.

However, recognizing the unique challenges and opportunities presented by the online medium, the content, activities, and pedagogies of the training were thoughtfully enhanced to suit the virtual environment. Throughout the developmental process, the feedback and insights from participating teachers and researchers were diligently collected and analyzed. These valuable inputs played a crucial role in refining and optimizing the online training program, ensuring that it catered to the needs and preferences of the teachers and effectively fostered their proficiency in implementing GeoGebra for mathematics instruction.

In summary, this study aimed to achieve two main goals: (1) developing an online training program for adept GeoGebra usage in math teaching and (2) assessing teachers' satisfaction with this program. The next section delves into the literature review.

2. Relevant Literature

GeoGebra, a dynamic software with distinct benefits for math instruction, stands as user-friendly freeware accessible to all. Particularly, its impact on students is profound; it visualizes abstract math concepts, enhancing understanding [4], encouraging exploration, and idea development. Additionally, teachers find GeoGebra advantageous in classroom pedagogy. This is demonstrated by its motivating impact on students [4] [5], offering dual roles: a teaching aid and a platform for student-led math exploration [5] [6]. These benefits foster a positive learning atmosphere, generating favorable perceptions of GeoGebra among educators and learners alike [6] [7]. Consequently, IPST has chosen GeoGebra as the tool to train Thai math teachers, equipping them to proficiently wield its basic functions and integrate it into instruction.

Amidst the COVID-19 pandemic, online training has emerged as a highly appropriate alternative, offering numerous advantages. One of the key benefits is its ability to mitigate virus exposure, ensuring the safety of participants [8]. Moreover, online training significantly expands access to learning opportunities [8]. Teachers from all regions of the country can easily attend training sessions, eliminating the need for travel expenses or accommodation when the training is held far from their homes.

Additionally, online training provides participants with enhanced flexibility [9]. They have the freedom to join the training from their preferred location, whether it be their home, office, or even a coffee shop, as long as they have internet access. This added convenience allows for a more comfortable and personalized learning experience, contributing to a more effective training process.

Nonetheless, conducting online training comes with its share of challenges. Research has indicated that a common drawback of online training is the absence of face-to-face communication and interaction, leading to potential difficulties in participants fully grasping the presented content [9]. Additionally, motivating participants in the online setting can be challenging [8]. Some individuals may attend the training from unsuitable locations or during inconvenient times, such as when they are at work, resulting in distractions that hinder their focus and engagement with the training activities. These factors can collectively impact the effectiveness and overall learning experience during online training sessions.

In the pursuit of developing a new online training program to help teachers effectively utilize GeoGebra for mathematics instruction, the researchers recognized the significance of two key aspects: promoting face-to-face communication and enhancing participants' motivation towards the training. Drawing from previous studies, the researchers discovered that synchronous online training held the potential to address these concerns [10]. By implementing synchronous online training, all participants engage in real-time activities, fostering immediate interactions between trainers and participants, as well as encouraging collaboration among the participants themselves.

Moreover, the researchers also acknowledged the importance of allowing participants to share their ideas, which was identified as a vital factor in boosting motivation [11]. As a result, the training framework incorporated the concepts of synchronous online training and idea-sharing to create an environment conducive to optimal learning and engagement. Further details about the training program can be found in the subsequent section.

3. The Study

This study developed an online training program with the objective of preserving a structure similar to IPST's onsite training program. The program's content and activities, drawn from the onsite version, centered on vital GeoGebra components: geometry, algebra, and statistics tools. This

selection recognized the time constraint teachers face in mastering all GeoGebra tools. Leveraging the software's user-friendliness, the training program aimed to equip teachers with basic tools' proficiency, empowering them to expand their skill set and generate teaching materials. Furthermore, the training included content on integrating GeoGebra into classroom instruction. To foster engagement and motivation, the program incorporated synchronous online training and idea-sharing. These strategies aimed to cultivate an immersive learning experience for all participants.

Subsequently, the researchers initiated the development of the initial draft for the online training program, tailored specifically for teachers aiming to use GeoGebra in mathematics instruction. The program was then implemented during the first phase of the study, as elaborated below.

The first phase of the study

During the initial phase of the study, the online training program for teachers centered around four distinct sections. The first three sections were dedicated to aiding teachers in acquiring proficiency in utilizing fundamental GeoGebra tools, including geometry, algebra, and statistics features within the software. The final section of this phase of the training program was designed to furnish concrete examples illustrating the practical implementation of GeoGebra in mathematics classroom instruction.

Within each section, the training commenced with a combination of lectures and interactive practice within the entire group. Upon completing the group activity, participants were presented with tasks or problems relevant to the content covered in that particular section. Subsequently, participants were divided into smaller groups, where they worked individually to tackle the assigned problems. After completing their individual tasks, each participant had the opportunity to present their work and share the ideas they employed to solve the problems.

Following the small group sessions, all participants reconvened in the whole group setting to collectively draw conclusions from the learning experiences and discussions held during the section. This comprehensive approach facilitated a dynamic and collaborative learning environment, enabling participants to benefit from both group interactions and individual exploration.

Examples of activities or given tasks in each sections were shown in Figure 1.

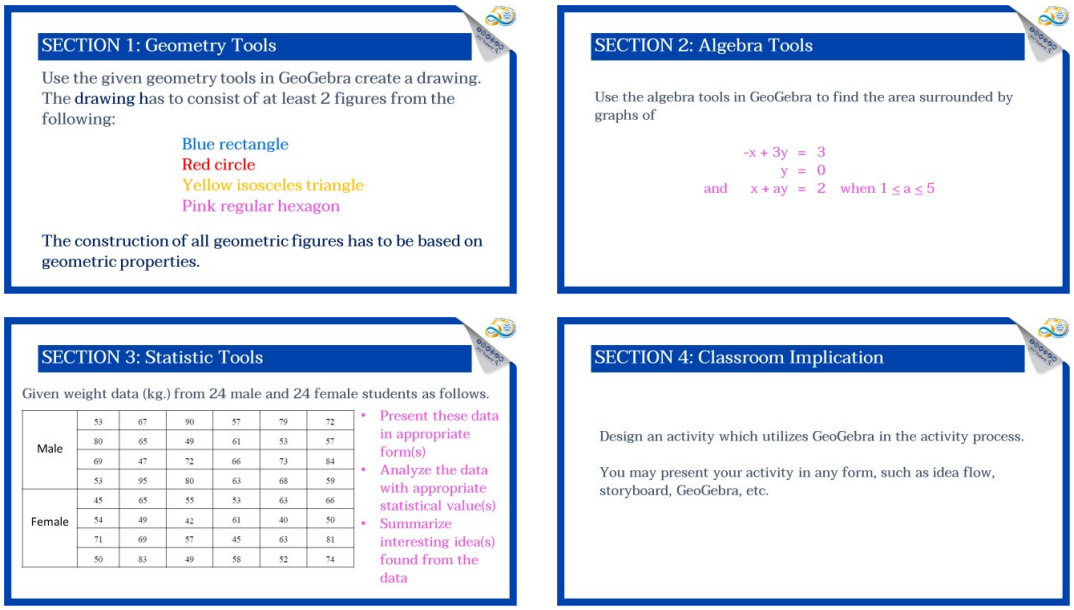

Figure 1 Examples of activities in each section

In April 2022, the online training program for the first phase of this study was conducted via the Zoom application, spanning a duration of two days. The training group consisted of 47 secondary mathematics teachers, chosen through stratified random sampling from 900 secondary mathematics teachers. The sampling method ensured representation from various regions of Thailand, including the northern, southern, northeastern, western, central, and Bangkok regions. Throughout the online training, all participants were required to attend every section, complete all assigned tasks, and submit their work for evaluation. This approach ensured comprehensive participation and engagement from the participants, fostering a meaningful and impactful training experience.

Upon the conclusion of the training, all participants were provided with an online survey. The survey comprised three demographic questions, seeking information on gender, age, and highest level of education completed. Additionally, participants responded to 11 Likert-type questions designed to gauge their satisfaction with the online training program. For instance, one question asked about their level of satisfaction with the training activities, with responses ranging from highly dissatisfied (1) to highly satisfied (5). Furthermore, the survey featured two open-ended questions, encouraging participants to provide their recommendations and feedback on the online training program.

The data collected from the demographic questions and the Likert-type questions were subsequently analyzed in terms of frequencies and percentages. This analysis aimed to offer valuable insights into the participants' basic characteristics and assess their overall satisfaction levels with the online training program.

Moreover, the recommendations and comments received from the open-ended questions were carefully summarized and considered for enhancing the training program during the second phase of the study. This feedback played a crucial role in refining the program to better meet the participants' needs and preferences, ensuring an improved and more effective training experience in the subsequent phase.

The second phase of the study

After analyzing the results from the survey, the researchers observed that incorporating small group activities significantly boosted participants' engagement during the online training. Nevertheless, it became apparent that the participants required additional time for the training, and they expressed the need for more examples of GeoGebra's implementation in mathematics classroom instruction.

In light of these findings, adjustments were made to the structure of the training program for this phase. The number of sections was reduced from four to three, with a primary focus on the fundamental tools within GeoGebra software, which were geometry, algebra, and statistics tools. Moreover, to address the participants' request for more practical guidance, examples of classroom implementation were integrated into all sections in form of discussion. This modification aimed to provide a more streamlined and comprehensive learning experience, allowing participants to gain deeper insights into GeoGebra's applications in mathematics instruction. Taking an algebra section for an example, once participants completed the assigned task resulting in the instructional material depicted in Figure 2, subsequent discussions would encompass topics such as:

- Where would you apply this material?
- How would you structure the activity if you were to implement this material?
- What questions would you pose if you conducted the activity using this material?
- How would you improve this material to be more beneficial for your activity?

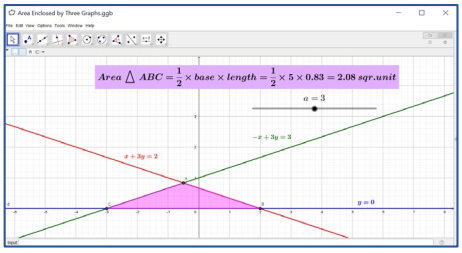

Figure 2 Example of completed task

The training in the second phase followed a similar approach to that of the first phase, encompassing various content and activities. These included lectures and interactive activities within the whole group, task assignments, division into small groups, individual work within these groups, presentations and discussions, and sharing of ideas followed by group conclusions within the whole group. Furthermore, the integration of GeoGebra into mathematics classroom instruction was a central aspect of the discussion, both in small group sessions and in the whole group setting across all sections.

As in the first phase, all participants in the second phase were required to engage in activities across all sections, participating in both whole group and small group settings. They were expected to complete all assigned tasks and submit their completed work for evaluation. Moreover, each participant was requested to complete an online survey similar to the one employed in the first phase. Subsequently, all collected data were analyzed for frequencies and percentages. Recommendations, feedback, and comments were summarized.

The findings derived from the implementation of the online training program designed for teachers to employ GeoGebra in mathematics instruction, encompassing both the first and second phases, are expounded upon in the subsequent section.

4. Results

The study's findings were from the first and the second phases of the study. More details of these results are provided in the following subsections.

Results from the first phase of the study

Out of the 47 secondary mathematics teachers who took part in the first phase of the study, 39 teachers (82.98%) completed and submitted the online survey. This group comprised five males (12.82%) and 34 females (87.28%). Approximately 40% of these participants were aged above 40 (38.46%), while another 25.64% fell within the age range of 26 to 30. In terms of educational qualifications, roughly half of the participating teachers had completed their bachelor's degree (51.28%), and the other half had attained their master's degree (48.72%).

Regarding participants' satisfaction with the online training program during the first phase, the rating for the content presented in whole group activities exceeded the 'satisfied level.' Detailed information is provided in Table 1.

Table 1

Frequencies and percentages of participants in each satisfied level for content presented in whole group activities in the first phase of the study

Indicator	Satisfied level				
	Highly dissatisfied	Dissatisfied	Neutral	Satisfied	Highly satisfied
Content in geometry section	0 (0.00%)	0 (0.00%)	2 (5.13%)	11 (28.21%)	26 (66.67%)
Content in algebra section	0 (0.00%)	0 (0.00%)	2 (5.13%)	12 (30.77%)	25 (64.10%)
Content in statistics section	0 (0.00%)	0 (0.00%)	1 (2.56%)	12 (30.77%)	26 (66.67%)
Content in classroom implementation section	0 (0.00%)	1 (2.56%)	2 (5.13%)	10 (25.64%)	26 (66.67%)

Table 1 illustrates that about 60 percent of the participating teachers expressed high satisfaction with the content presented in the geometry, algebra, statistics, and classroom implementation sections. This indicates that the content within these sections was well-suited for online training. However, it is noteworthy that one teacher felt dissatisfied with the content provided in the classroom implementation section.

Furthermore, the participating teachers' satisfaction with the small group activities during the first phase of the online training program surpassed the 'satisfied level,' as indicated in Table 2.

Table 2

Frequencies and percentages of participants in each satisfied level for small group activities in the first phase of the study

Indicator	Satisfied level				
	Highly dissatisfied	Dissatisfied	Neutral	Satisfied	Highly satisfied
Small group trainer's ability					
Explanation	0 (0.00%)	0 (0.00%)	3 (7.69%)	4 (10.26%)	32 (82.05%)
Language used	0 (0.00%)	0 (0.00%)	2 (5.13%)	6 (15.38%)	31 (79.49%)
Response to question	0 (0.00%)	0 (0.00%)	1 (2.56%)	9 (23.08%)	29 (74.36%)
Task given in					
Geometry section	0 (0.00%)	0 (0.00%)	1 (2.56%)	12 (30.77%)	26 (66.67%)
Algebra section	0 (0.00%)	1 (2.56%)	1 (2.56%)	11 (28.21%)	26 (66.67%)
Statistics section	0 (0.00%)	0 (0.00%)	1 (2.56%)	11 (28.21%)	27 (69.23%)
Classroom implementation section	0 (0.00%)	0 (0.00%)	1 (2.56%)	13 (33.33%)	25 (64.10%)

As shown in Table 2, over 70 percent of the teachers expressed high satisfaction with the trainer's abilities to explain concepts, use language effectively, and respond to participants' questions in the small group setting. Regarding the tasks given in each section, around 65 percent of the teachers reported high satisfaction, while approximately 30 percent expressed satisfaction. However, it is worth noting that around five percent of the teachers rated their satisfaction at unsatisfied to neutral levels. This suggests that some participants may have encountered difficulties in solving the tasks provided in each section.

Additionally, two significant recommendations emerged from both the participating teachers and the researchers who closely observed each small group. Firstly, the participants expressed a need for more time in each section. They required additional time during the whole group activities, particularly when learning to use geometry, algebra, and statistics tools. Moreover, they also requested more time to collaborate in small groups, allowing them to effectively complete the assigned tasks.

Secondly, participants pointed out that the examples provided in the classroom implementation section predominantly focused on algebra tools. They expressed a desire to see more examples that were related to geometry and statistics tools, enabling them to gain a comprehensive understanding of GeoGebra's application across various mathematical concepts.

Taking these valuable recommendations and comments into account, the researchers proceeded to revise the online training program, incorporating the necessary adjustments and improvements. This revised program was then implemented during the second phase of the study, aiming to create an enhanced and tailored learning experience for the participants.

The findings from the second phase of the study are outlined in the next subsection.

Results from the second phase of the study

Out of the 61 secondary mathematics teachers who participated in the second phase of the study, 42 teachers (68.85%) submitted the online survey. This group comprised two male teachers (4.76%) and 40 female teachers (95.24%). The majority of teachers fell within the age categories of 20 to 30, more than 40, and 36 to 40 (30.95%, 26.19%, and 23.81% respectively). Nearly all participants had completed either a bachelor's or master's degree (27.62% and 47.62% respectively). Additionally, 4.76% of the participants had attained a degree higher than a master's degree.

Regarding participants' satisfaction with the online training program in the second phase, the rating for the content presented in whole group activities exceeded the 'satisfied level.' Further details are provided in Table 3.

Table 3

Frequencies and percentages of participants in each satisfied level for content presented in whole group activities in the second phase of the study

Indicator	Satisfied level				
	Highly dissatisfied	Dissatisfied	Neutral	Satisfied	Highly satisfied
Content in geometry and the implication section	0 (0.00%)	0 (0.00%)	2 (4.76%)	16 (38.10%)	24 (57.14%)
Content in algebra and the implication section	0 (0.00%)	0 (0.00%)	2 (4.76%)	14 (33.33%)	26 (61.90%)
Content in statistics and the implication section	0 (0.00%)	0 (0.00%)	2 (4.76%)	18 (42.86%)	22 (52.38%)

Table 3 reveals that approximately 95 percent of the participating teachers expressed satisfaction and high satisfaction with the content presented in the geometry and implementation, algebra and implementation, and statistics and implementation sections. This highlights the highly appropriate content within these sections for online training.

Moreover, the participating teachers' satisfaction with the small group activities during the second phase of the online training program exceeded the 'satisfied level,' as indicated in Table 4.

Table 4
Frequencies and percentages of participants in each satisfied level for small group activities in the second phase of the study

Indicator	Satisfied level				
	Highly dissatisfied	Dissatisfied	Neutral	Satisfied	Highly satisfied
Small group trainer's ability					
Explanation	0 (0.00%)	0 (0.00%)	3 (7.14%)	10 (23.81%)	29 (69.05%)
Language used	0 (0.00%)	0 (0.00%)	3 (7.14%)	10 (23.81%)	29 (69.05%)
Response to question	0 (0.00%)	0 (0.00%)	2 (4.76%)	10 (23.81%)	30 (71.43%)
Task given in					
Geometry and the implication section	0 (0.00%)	0 (0.00%)	2 (4.76%)	15 (35.71%)	25 (59.52%)
Algebra and the implication section	0 (0.00%)	0 (0.00%)	3 (7.14%)	12 (28.57%)	27 (64.29%)
Statistics and the implication section	0 (0.00%)	0 (0.00%)	4 (9.52%)	14 (33.33%)	23 (54.76%)

Table 4 displays that around 70 percent of the teachers expressed high satisfaction with the trainer's abilities to explain concepts, use language effectively, and respond to participants' questions in the small group setting. Regarding the tasks given in each section, about 60 percent of the teachers reported high satisfaction, and approximately 30 percent indicated satisfaction. Notably, no teachers reported feeling highly dissatisfied or dissatisfied with the tasks provided in the small group activities. This suggests that the given tasks across all sections were deemed appropriate by the participants in terms of content and time allocation.

In summary, participants' comments from the online survey indicated that the training duration in the second phase (3 days) was considered appropriate. Furthermore, several recommendations surfaced, which could prove beneficial for future training endeavors. Firstly, teachers preferred future training sessions to be scheduled on weekends or holidays to avoid conflicts with their weekday school responsibilities. Secondly, teachers expressed a desire to delve deeper into the functionalities of algebra, geometry, and statistics tools in GeoGebra, including learning about writing command language and scripting language.

Thirdly, participants expressed a need for future training that specifically focused on using GeoGebra to create mathematical media for certain subjects, such as 3-D geometry, geometrical analysis, and calculus. Lastly, there was interest in training sessions tailored to the implementation of GeoGebra in classroom instruction, specifically catering to participants who were already familiar with the basic tools in GeoGebra. These valuable recommendations are valuable insights that can help shape and enrich future training programs to better meet the needs and preferences of the participants.

5. Conclusion and Discussion

The primary focus of this study was on developing an online training program specifically designed for teachers to effectively use GeoGebra in mathematics instruction. Drawing inspiration from IPST's successful onsite training in this area, the developed online program aimed to achieve two main objectives: facilitating teachers' understanding of the basic tools available in GeoGebra

software, including geometry, algebra, and statistics tools, and demonstrating how GeoGebra can be effectively implemented in classroom instruction.

During the developmental process, the researchers recognized and addressed two major challenges commonly encountered in online training: the potential lack of participant interaction and motivation. To deal with these issues, the study incorporated two key pedagogical strategies into the training program. Firstly, the concept of synchronous online training was adopted, ensuring real-time interactions and fostering engagement among participants. Secondly, the training program encouraged active idea sharing, allowing participants to exchange thoughts and insights. These pedagogical concepts were implemented in both the online training programs used during the first and second phases of the study, aiming to create a dynamic and enriching learning experience for all participants.

During the first phase of the study, the online training program, consisting of four sections (geometry, algebra, statistics, and classroom implementation), effectively met the participants' needs. Additionally, upon reviewing the tasks submitted by the participants, the researchers observed that the teachers engaging in the training demonstrated proficiency in using basic tools within GeoGebra and displayed creative ideas for implementing GeoGebra in classroom instruction.

However, a significant constraint encountered by the participants was time limitation. The allocated time posed challenges in both learning the basic tools of GeoGebra and completing the given tasks. Despite this constraint, the time pressure was slightly decreased during the small group activities. In these sessions, participants benefited from close observation and peer assistance, provided by both group members and the group trainer. Such support contributed to a more conducive and interactive learning environment, allowing participants to navigate the constraints more effectively.

In the second phase of the study, the focus shifted towards the application of GeoGebra in classroom instruction, in addition to learning the basic tools. Consequently, the online training program for the second phase comprised three sections: geometry and its implication, algebra and its implication, and statistics and its implication.

Compared to the first phase, the training duration for the second phase was extended to three days, providing more time for comprehensive learning and exploration. Overall, the participating teachers in the second phase expressed satisfaction with the online training program. As in the first phase, they exhibited proficiency in using basic tools within GeoGebra and demonstrated creative ideas for implementing GeoGebra in classroom instruction. Moreover, the participants expressed their interest in attending future training sessions (either onsite or online) focused on the usage of GeoGebra, particularly in creating instructional media for specific mathematical content.

However, the results on the participants' satisfaction with the online training, primarily centered around synchronous learning and idea sharing, was as anticipated. Previous research has consistently shown that in online learning, participants tend to express greater satisfaction with synchronous learning environments as they offer enhanced opportunities for discussions and idea exchange, ultimately boosting learning outcomes [12] [13].

Nevertheless, several variables could have influenced the findings. For instance, the participants' abilities in using GeoGebra tools might have been influenced by the increased digital literacy among teachers during the COVID-19 pandemic, as many had to adapt to online teaching. Additionally, the teachers' satisfaction with the online training program might have been influenced by the lack of training experiences for a long time during the COVID-19 pandemic. To ensure the integrity of future implementations of the online training program, these variables should be carefully controlled and taken into consideration.

In conclusion, the developed online training program for teachers in using GeoGebra for mathematics instruction proved to be effective in helping teachers acquire proficiency in using basic tools within the GeoGebra software. Moreover, the training provided valuable insights into the

implementation of GeoGebra in mathematics instruction. Significantly, the participating teachers expressed high satisfaction with the online training program.

However, to fully understand the advantages of this online training program under normal circumstances, it would be beneficial to repeat the study after the end of the COVID-19 pandemic. This future study could provide a comprehensive comparison of the training program's effectiveness and outcomes in a non-pandemic setting, offering further insights into its impact on teacher learning and classroom instruction.

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