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The Influence of Integrating GeoGebra Software into the Educational Setting on the Affective, Behavioral, and Cognitive Aspects of Pre-Service Mathematics Teachers

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Abstract

This study investigates pre-service teachers' attitudes toward mathematics and math teaching using GeoGebra. The research employs attitudes questionnaires to assess beliefs and explores the impact of high-tech software on educational patterns. The study involves 80 pre-service teachers attending GeoGebra courses at Sakhnin Academic College in Northern Israel. Findings reveal enhanced emotional and behavioral aspects for the majority, though cognitive improvement is not observed uniformly. Two distinct groups emerge: one showing no significant change (10%) and another with significant improvement (90%). The study suggests a shift toward investigating practices for bridging theory and practice, emphasizing the importance of collaborative work in enhancing attitudes and critical thinking skills.

Keywords

Affective Components, Behavioral Components, Cognitive Components, Educational Technology, GeoGebra Software

1. Introduction

Each year, a substantial volume of research papers explores the integration of GeoGebra in mathematics instruction. However, there is a noticeable gap in the literature when it comes to comprehensive and specific investigations on the utilization of GeoGebra for teachers' professional development within the Israeli educational system. While there is no consensus on the optimal model or strat-

egy, a majority of scholars concur that teacher education programs should incorporate technology integration as a means to support the enhancement of new teachers' skills and professional advancement.

GeoGebra is a dynamic mathematics program with an intuitive user interface that combines algebra, geometry, spreadsheets, graphing, and calculus. With its interactive and visual representations, GeoGebra, an educational tool, lets users investigate mathematical ideas. Real-time mathematical relationship visualization, algebraic equation manipulation, and geometric creation are all possible for users. The software is a useful tool for both students and teachers because it supports a broad range of educational levels, from kindergarten to university. GeoGebra has gained popularity as a tool for teaching and studying mathematics because of its open-source design and cross-platform compatibility, which encourage an interactive and hands-on approach to mathematical discovery and comprehension.

The integration of technology in educational programs worldwide has been addressed through various methods and strategies. However, researchers have yet to reach a consensus on the most effective approach, or perhaps a combination of approaches, for incorporating technology in teacher education programs. A significant initiative in this regard was the publication of the book "Educating Tomorrow's Teachers on how to Utilize Technology" by the United States Department of Education (USDOE). Recognizing the need to incorporate technological tools into the educational process, the USDOE allocated a substantial amount of funding, exceeding $750 million, to promote a shift in organizational practices within teacher training at the apprentice level (Tondeur et al., 2012). Between 1999 and 2003, more than 400 grants were awarded to higher education institutions, government agencies, schools, and NGOs, fostering collaboration and facilitating a deeper understanding of the issue. This endeavor aimed to enable the redesign of teacher training programs to cater to the learning needs of the 21st century (Polly et al., 2010).

A pedagogical course has been designed with the aim of enhancing the targeted pre-service teachers' (PSTs) skills through integrated approaches. By integrating technology into the teacher training curriculum, an endeavor is being made to bridge the gap between traditional teaching techniques in mathematics and their innovative and creative counterparts. The study utilizes GeoGebra, a sophisticated software that requires prior experience in computer technology and intellectual openness. It encourages PSTs to think outside the box and explore various problem-solving approaches that diverge from conventional methods.

The study has three primary objectives. Firstly, it seeks to conduct a comprehensive scientific analysis of the changes in PSTs' attitudes towards mathematics following the implementation of the program. Secondly, it aims to determine whether the adoption of the software has influenced the pre-service teachers' attitudes towards mathematics instruction. The third objective is to identify the distinctive characteristics of GeoGebra that contribute to the modification of

specific attitudes related to the teaching of mathematics.

These three study objectives were selected based on practical assumptions, which were subsequently refined through practical implementation. With each cycle of the study, the initial hypothesis—"It is possible to discover various methods, techniques, and strategies to increase the motivation of mathematics PSTs towards mathematics and enhance their teaching simultaneously"—was adjusted based on data from subsequent reflection phases and ongoing analysis of existing research in the field.

The central claim of this study asserts that the incorporation of GeoGebra, along with the development, implementation, and evaluation of a teaching process, can bring about a positive transformation in pre-service teachers' perceptions of Math Education. The introduction of GeoGebra is expected to enhance specific attitudes and competencies to a higher level, with certain attributes of the software inevitably influencing changes in the attitudes of individual pre-service teachers. The research assumes that the advantages of GeoGebra have an impact on the transformation of pre-service teachers' attitudes.

This paper addresses a complex educational debate regarding the effectiveness of integrating high-tech software into a traditional teaching and learning environment. The challenge lies in establishing the reliability and benefits of this approach, which should be perceived as certain by participants. To overcome this challenge, the authors propose a solution wherein the research community responsible for developing the program should alleviate existing conflicts or reservations and convince users to reconsider their stance for their own benefit. The desired outcome is a tangible transformation in pre-existing attitudes, perceptions, behaviors, and practices within the research community, which previously operated in a technology-deficient environment.

One notable limitation of the study is the scale of the experimental examination, which involved a sample of 80 pre-service teachers divided into three student groups. The participants were enrolled at Sakhnin Teachers' College in Northern Israel, the targeted institution where the study was conducted with strict adherence to procedures. These groups represented the cognitive and attitudinal profiles that are common among the majority of Israeli Arab pre-service teachers, thus suggesting that the conclusions may have relevance for homogeneous populations. The choice of a collaborative framework was made to address this limitation, as it promoted communication and beneficial interaction among the participants. However, this methodological decision, while effective, can introduce a new constraint to the investigation. In some instances, concerns arose regarding whether the same outcomes could have been achieved by individual pre-service teachers working alone with GeoGebra. The significance of classmate interaction in certain situations and its influence on the cognitive development of one or both partners made it challenging to differentiate between the individual effects of the software and the collaborative group work.

The central assertion of this study is that by incorporating GeoGebra, a teaching

process can be developed, implemented, and evaluated to bring about a positive change in pre-service teachers' perception of Math Education. The introduction of GeoGebra is expected to foster the development of specific attitudes and competencies at an advanced level. To ensure the credibility and accuracy of the collected information and mitigate the influence of existing limitations, the researchers consciously chose to gather data through both oral and written means. They also combined data from both paired and individual activities, in addition to the previously mentioned measures.

2. Related Works

2.1. Pre-Service Teachers' Attitudes and Beliefs

Prior research in the field has reached a near-consensus on the inclusion of cognitive, affective, and behavioral components in attitudes (Crano & Prislin, 2006). This triadic conceptualization of attitudes served as the foundational premise for the current study. Numerous studies have explored the interrelationships among these components within pre-service teachers' attitudes towards mathematics in a broader context. Notably, Letwinsky (2017) stands out among the relevant studies in this regard. The study highlights the potential of sophisticated pedagogical software to provide pre-service teachers with unique opportunities to extend mathematics communication beyond the confines of the traditional classroom. Additionally, it suggests the need to investigate why teachers who display positive indicators for technology integration do not solely rely on the potential of communication technology to foster mathematics communication and literacy. These earlier investigations align with the central theme of the present study, which revolves around the introduction of GeoGebra software into the educational environment.

Furthermore, Beswick and Fraser (2019), who also emphasizes the significance of an important approach to the growth and development of pre-service teachers, argues that integrated approaches to STEM disciplines education offer enhanced opportunities for cultivating these skills. Such opportunities hinge upon teachers possessing expertise in one or more relevant disciplines. Drawing from their initial experiences as students, pre-service math teachers bring forth the necessary knowledge and pre-existing perspectives on teaching and learning processes. These factors eventually influence their attitudes, behavioral aspects, and overall performance within mathematical environments (McDonald et al., 2014). Both McDonald et al. (2014) and Ertmer et al. (2012) argue that the primary barriers to integrating technology in the classroom are not as significant as previously assumed, such as barriers related to access and support. Both studies reaffirm the relevance of participants' cognitive and behavioral characteristics to the present research.

2.2. Influence of Previous Schooling

Dorner and Kumar (2016) posits that the influence of technology integration

begins even before pre-service teachers embark on their formal training programs. Furthermore, the research conducted by Tiba and Condy (2021) indicates that pre-service teachers who expressed a greater inclination to incorporate technology in their future careers were those who reported having a technology-rich experience during their high school years. Similarly, Seifert (2015) obtained comparable findings in their study which explored the use of advanced software in smartphone applications, delving into the pedagogical extensions of smartphone integration in the broader teaching process. These three preceding studies all support the introduction of modern technologies into traditional educational settings, a characteristic shared with the present study.

Given their upbringing in a technologically pervasive environment, many pre-service teachers are often referred to as digital natives (Teo, Kabakçı Yurdakul, & Ursavaş, 2016). The concept of digital nativity was thoroughly examined by Wilson, Hall, and Mulder (2022), who assessed digital nativity among pre-service teachers by examining the assessment criteria associated with digital natives and its practical implications. Several industry experts argue that being digital natives and having grown up surrounded by technology implies a high level of technological proficiency. However, Jones (2012) contend that while the notion of digital nativity is appealing, there is still a dearth of substantial evidence to substantiate such claims. Clearly, both (Teo, Kabakçı Yurdakul, & Ursavaş, 2016; Wilson, Hall, & Mulder, 2022) address the first and third objectives of the study in a scholarly manner, while the second objective is explicated by (Jones, 2012).

2.3. Changing Teachers' Beliefs

The consensus among experts is that teachers' beliefs are often resistant to change due to their real-life experiences. However, the introduction of technology, living in a technologically advanced environment, and utilizing state-of-the-art software have the potential to facilitate significant transformations. This underlying premise aligns with the objectives and relevance of the present study (Ertmer, 2005; Pajares, 1992). Ruggiero and Mong (2015) explored strategies and tactics that could facilitate belief change among teachers, as their beliefs and practices are continually influenced by the values prevailing in their environment. Similarly, Hakim (2015) conducted an in-depth investigation into how pre-service mathematics teachers perceive their preparedness to teach mathematics using technology as a primary tool. Their findings revealed a positive correlation between constructivist instructional practices and increased utilization of technology during student teaching. Both Ruggiero and Mong (2015) and Hakim (2015) examined pre-service teachers' belief systems and explored their perceptions of mathematics as an abstract subject, which aligns with the goals of the current study.

2.4. Teachers' Attitudes towards Mathematics and Mathematics Education at Large

Numerous scholars have extensively investigated and demonstrated the significance of instructors' attitudes toward mathematics. Notably, Philippou and

Christou (1998) made a significant discovery by establishing a robust correlation between math teachers' classroom practices, overall observable behaviors, and their attitudes toward mathematics. Similarly, the study conducted by Philippou and Christou (1998) explored the implementation of integrated STEM education as a progressive strategy to effectively enhance students' achievement and interest in STEM fields, yielding highly valuable findings. However, despite the profound importance of individual attitudes, it is disheartening to note that many pre-service teachers (PSTs) commence their careers with negative attitudes toward mathematics (Letwinsky, 2017; Philippou & Christou, 1998). This prevailing issue underscores the criticality of addressing and transforming these attitudes. In relation to the study's second objective, Philippou and Christou (1998) specifically focused on analyzing participant behavior and established connections between any visible changes observed and the integration of technology within the instructional process.

2.5. Categories and Sub-Categories of Mathematics Learning and Teaching

Numerous scholarly investigations have meticulously explored and documented specific attitudes that constitute essential elements of desirable mathematics attitudes for pre-service teachers (PSTs). These attitudes include, but are not limited to, cognitive flexibility, a spirit of critical thinking, focused attention and effort, artistic expression, a self-reliant mindset, and a systematic approach. Notably, these contributions are extensively discussed by Turner et al. (2012), who argues that the acquisition of knowledge, well-defined inclinations, and actions that foster the development of existing cognitive skills are fundamental components of effective learning. In a similar vein, Turner et al. (2012) emphasizes that the aforementioned skills and categories are applicable to both teachers and students, and their cultivation undoubtedly influences attitudes toward learning and teaching. Consequently, the three objectives proposed in the present study are closely aligned with the overarching emphasis on the abilities and competency factor underscored by Turner et al. (2012) in the context of pre-service teachers.

3. Methodology

3.1. Participants

The study community consisted of (80) PST's in their second to fourth year of academic enrollment, who were attending (3) "GeoGebra" courses as pursuing their math teaching qualification at Sakhnin Academic College for Teacher Education in Northern Israel.

3.2. Procedures

In the initial course, the participants displayed an average level of performance without any notable achievements or difficulties. However, they exhibited a ten-

dency to become easily distracted from assigned tasks and struggled to maintain focus, despite the rich dialogue present in the learning environment. The researchers anticipated that introducing GeoGebra would enhance motivation, increase overall engagement, and foster qualities such as dedication, perseverance, and persistence among the participants. This expectation was based on the fact that most of the participants were accustomed to investing time in completing homework assignments.

Similar patterns of behavior were observed among the participants in the second course. However, throughout the third course, there was a noticeable increase in the number of students experiencing cognitive difficulties, resulting in subpar overall performance due to a relatively slow and tiresome work rate.

To gain a comprehensive understanding of pre-service teachers' attitudes toward mathematics, the researchers employed various data collection methods. The attitudes observation grid was utilized to observe the participants' performance on given tasks, providing valuable insights. Both observational (O) and non-observational (NO) technologies were employed during the continuous analysis phase, enabling the collection of relevant data. However, due to the complexity of integrating the collected data, providing a concise description of the process became challenging.

To assess the impact of the GeoGebra program on pre-service teachers' attitudes and perceptions of mathematics, a questionnaire named "I need your opinion" was employed. This survey aimed to capture any changes in attitudes and perceptions resulting from collaborative use of the recommended software. It also sought to gauge participants' feelings towards teaching mathematics and their preferences for teaching strategies, including attitudes towards computer use and collaborative work in mathematics. The data obtained from the participants was coded and analyzed in the first step, and subsequent data triangulation will allow for a comprehensive understanding of the attitude changes exhibited by each pre-service teacher in the two categories. Additionally, information gathered during introductory technology courses will be carefully examined to explore any potential relationships between the two groups.

3.3. Validity and Credibility of the Study Tool

To achieve their research objectives, the researchers utilized a questionnaire titled "I need your opinion" to capture the changes in pre-service teachers' attitudes and perceptions of mathematics resulting from the inclusion of the GeoGebra program. This survey aimed to assess how the participants' attitudes towards mathematics evolved through collaborative use of the recommended software. Additionally, it sought to explore the participants' sentiments regarding teaching mathematics and their preferences for teaching strategies, specifically examining attitudes towards computer use and collaborative work in the context of mathematics education. The questionnaire specifically inquired about the participants' attitudes during their engagement with the software and whether

they noticed any shifts in their attitude towards incorporating technology during that period.

These questionnaires are based on the scale of attitudes toward mathematics, a proven assessment tool (ATCLM). The questionnaires are made up of a series of statements, the answers to which were categorized into five groups (from strongly disagree to strongly agree, with the corresponding option of indecision serving as the center point) with the idea that the data would be useful for research and simple to use.

4. Results and Discussion

4.1. Attitudes towards Math Questionnaire

The researchers conducted a descriptive (SPSS), statistical analysis of the PSTs' answers before performing an inferential analysis. Table 1 presents the calculations obtained.

Table 1 demonstrates that there was a minor improvement in the cognitive component while a decline was observed in the affective component. In terms of the applicability dimension, a significant proportion of pre-service teachers participating in the pre-test and post-test acknowledged the practical relevance of mathematics in real-life situations and recognized its value as a useful tool for the future.

Following the initial analysis, the researchers conducted more detailed investigations to identify statistically significant differences between the responses of the 80 students in the pre-test and post-test. Tests were performed using SPSS, including a dependent samples t-test and two non-parametric tests (Wilcoxon signed-rank test and sign test). These tests revealed significant differences, particularly in the emotive component (items 12, 25, and 29) and the applicability dimension (items 18 and 26).

The researchers observed that changes in item 12, which pertains to feeling tension and discomfort in arithmetic class, had an impact on the affective component. The agreement rate increased from 22.5% in the pre-test to 35% in the post-test. Similarly, item 25, indicating a desire for top grades in mathematics, showed a decrease from 100% in the pre-test to 95% in the post-test. Conversely, item 29, expressing a wish for mathematics to not exist, saw an increase from 15% in the pre-test to 25% in the post-test.

Table 1. Percentages of PSTs attitudes towards Mathematics according to the opinions reflected in the pre-test and posttest.

	Cognitive		Affective		Applicability	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Negative	5	7.5	2.5	7.5	7	10
Neutral	10	5	5	7.5	12.5	10
Positive	85	87.5	92.5	85	80.5	80

Regarding the applicability dimension, changes were observed in item 18, which reflects the belief that mathematics will be useful in the future. Despite a slight decrease in agreement on the post-test, a majority of pre-service teachers still expressed agreement with the statement. For item 26, which highlights the importance of solid mathematics skills for future careers, there was a slight reduction in agreement from 97.5% in the pre-test to 92.5% in the post-test. Inferential analysis supported the conclusion from the statistical analysis that there were no statistically significant changes between the pre-test and post-test.

In conclusion, while the pre-service teachers' perspectives on mathematics remained relatively stable before and after the introduction of GeoGebra, the instrument did not reveal any significant or noticeable changes in their responses. Initial examination did not uncover significant shifts in the pre-service teachers' opinions. Consequently, the researchers conducted various means comparison analyses, including a dependent samples t-test and two non-parametric tests (Wilcoxon signed-rank test and sign test) using SPSS, in order to explore potential significant differences between the pre-test and post-test responses of the pre-service teachers.

4.2. Attitudes towards Mathematics Teaching

A factorial analysis was conducted on the questionnaire items, resulting in their classification into four categories that account for 51.131% of the total variance. The items within each factor/category are presented in descending order based on their significant contribution to that factor (an item is associated with a factor if its weight exceeds 0.40 and is higher for that factor compared to others). The subsequent step involved interpreting the defining items within each factor to assign an appropriate title that accurately reflects the gathered information.

The findings presented in Table 2 indicate that 60% of pre-service teachers (PSTs) who hold positive attitudes towards the use of information and communication technology (ICT) in mathematics and perceive the benefits of GeoGebra collaboration reported a satisfactory experience with GeoGebra in their mathematics

Table 2. Means of pre-service teachers according to opinions reflected in the preliminary analysis of NYO (need your opinion factors).

		Factor 1: Attitude towards the use of ICT/GeoGebra in Mathematics	Factor 2: Advantages of the incorporation of GeoGebra	Factor 3: Rejecting Mathematics using GeoGebra	Factor 4: Work Collaboratively using GeoGebra
Statistical description	Maximum	2.34	2.27	2.25	3.27
	Minimum	−1.73	−1.67	−2.53	−1.21
	Standard Deviation	1.00	1.00	1.00	1.00
Attitude (%)	Negative	47.5	48.0	37.5	48.0
	Neutral	0.00	0.00	0.00	0.00
	Positive	52.5	52.00	62.5	52.0

work. Each component of attitudes—cognitive, affective, and behavioral—was examined separately, providing valuable insights into PSTs' attitudes towards mathematics teaching and learning.

Regarding the cognitive component, a majority of students (72.1%) expressed increased reliance on their own abilities (item 9), while 65.3% believed they could understand mathematics independently using ICT (item 19). These statistical data suggest that the use of GeoGebra has contributed to an enhancement in students' self-confidence and competence in mathematics (cognitive component).

In terms of the affective component, a high percentage of participants (87.5%) found the course interesting when using computers (item 2), with only a small proportion (7.5%) expressing a lack of enjoyment in the assigned tasks. Thus, the inclusion of GeoGebra has positively influenced pre-service teachers' emotional attitudes towards learning and teaching mathematics. Regarding the behavioral component, the survey findings revealed that 85% of participants reported greater engagement and success in mathematical assignments when using ICT (item 1).

Regarding PSTs' attitudes towards the use of ICT in mathematics, a significant proportion (63%) indicated increased confidence as a result of using computers (item 3). Similarly, 85% of PSTs expressed a strong desire to study mathematics (item 6). The majority (70%) believed that using GeoGebra made dealing with arithmetic less challenging than usual (item 10). These findings collectively indicate a predominantly positive attitude towards the use of ICT in mathematics.

PSTs' attitudes towards collaborative work with GeoGebra were also examined, with the majority (77.5%) expressing a preference for teamwork, while the remaining PSTs preferred working alone (item 22). Notably, 92.5% of students believed that this approach to learning had improved their relationships with classmates (item 4). Interestingly, PSTs reported that the integration of GeoGebra facilitated easier error recognition and provided abundant resources that contributed to a better overall comprehension of mathematical concepts.

In summary, the results demonstrate that PSTs' attitudes towards the use of GeoGebra and ICT in mathematics were generally positive. The inclusion of GeoGebra in their mathematics work had a positive impact on their cognitive, affective, and behavioral components of attitude. Additionally, the cooperative work with GeoGebra was well-received by the PSTs, leading to improved teamwork skills and enhanced understanding of mathematical materials.

Notable improvement was observed in numerous mental, behavioral, and personal facilities due to the effective employment of Geogebra in mathematics teaching and learning, and within a technology-rich educational ambience. Among the areas profoundly impacted by the prior are the following:

- **Flexibility of Thought**: The results indicate that a significant portion of the surveyed pre-service teachers experienced a positive shift in their attitudes. The interactive feedback provided by the software played a crucial role in facilitating this transformative change in mindset, aligning with the emphasis

placed on these factors by previous researchers (Raya-Fernández & Sánchez Cruzado, 2022).

- **Critical Spirit**: The study reveals that two distinct features of GeoGebra played a pivotal role in facilitating attitude changes among the pre-service teachers (PSTs). These features were internalized by the PSTs, leading them to place reliance on the outcomes despite being aware of the potential errors that could arise from improper utilization of these features. The findings of the study align with the assertions made by Olsson (2019), suggesting that the expertise of the PSTs motivated them to proactively identify and rectify potential flaws, deviating from the conventional approaches used in task completion.
- **Perseverance**: The aforementioned mindset is particularly relevant to the motivating aspect of the software. In line with the findings of Kartal and Çınar (2022), it can be inferred that the integration of the software is correlated with the expressed confidence of pre-service instructors in effectively resolving mathematical problems.
- **Precision and Rigor**: The positive shift in attitude observed among the participating pre-service instructors can be attributed to the utilization of two prominent GeoGebra features: accurate calculations and visible representations. These features proved to be highly responsive and user-friendly, enabling the pre-service instructors to efficiently and swiftly create graphic structures. A similar finding was highlighted by Kartal and Çınar (2022), who emphasized the introduction of precision and rigor in students' work through the integration of GeoGebra, thus corroborating the aforementioned outcome.
- **Creativity**: While the previous analyses indicated that GeoGebra did not directly contribute to the evolution of attitudes among the majority of pre-service teachers (PSTs), it was observed that those who demonstrated flexible and autonomous thinking approached the software in a more creative manner. In relation to this finding, consistent with the findings of Ziatdinov and Valles Jr. (2022), the software itself did not directly lead to an improvement in this specific attitude. However, it can indirectly influence it by positively impacting other relevant attitudes.
- **Autonomy**: The software is widely recognized for providing users with a plethora of alternatives and opportunities to explore and experiment with different strategies in a constructive manner. Additionally, the software offers various modes and pathways for exploration. One remarkable feature of this advanced technological tool is its ability to empower pre-service teachers, allowing them to build their confidence and take direct control of their own learning process. This conclusion aligns with the findings of Mavani (2020), who extensively examined the concept of autonomy and its relationship to the successful integration of the software. The findings presented in this segment are in line with the findings of Assadi & Hibi (2020).

- **Systematization**: The key element of GeoGebra that held significant importance in this context was its interactive nature, which facilitated dynamic manipulation of mathematical structures and provided real-time feedback to pre-service teachers. The previous functionality of the program was also examined and discussed by Martínez-Sevilla and Alonso (2022), who likewise acknowledged that this feature enabled users to assess and validate proposed theories.

The researchers held a strong belief that actively incorporating the GeoGebra software would have a positive impact on the three components of attitudes towards mathematics, which was supported by earlier investigations and field experience (Kartal & Çinar, 2018; Tamam & Dasari, 2021). These findings align with previous research such as Khali and Khalil (2019), which examined the changes observed in teachers who assessed their students' use of ICT for problem-solving. The ability to take initiative, support application, demonstrate dedication, defend ideas, and show inventiveness were notable characteristics observed in participants' problem-solving abilities and comprehension of worksheets.

The research conducted supports the conclusion that the pre-service teachers (PSTs) perceived GeoGebra as an effective tool for problem-solving, leading to increased engagement, self-confidence, and positive views about mathematics, as discussed in (Cevikbas & Kaiser, 2021). Similar support for these findings can be found in Zambak and Tyminski (2020), where middle school pre-service mathematics teachers (PSMTs) utilized advanced dynamic geometry software and the Geometer's Sketchpad as a cognitive tool. A case study from Zambak and Tyminski (2020) identified five levels of mathematical knowledge for teaching (MTK) that explained how PSMTs perceived and utilized the capabilities, features, and limitations of GeoGebra.

In accordance with Bernard and Setiawan (2020), three specific attributes of GeoGebra were found to have a positive influence on attitudes towards mathematics and its cognitive, affective, and behavioral aspects. These findings also align to some extent with (Voica, Singer, & Stan, 2020).

The majority of PSTs reported that working with GeoGebra not only provided pleasure and confidence but also increased their interest in the subject and active involvement in math-related tasks. This, in turn, enhanced their confidence in succeeding in their future careers, which is consistent with the findings of (Lyublinskaya & Tikhomirova, 2019). The favorable adjustment in PSTs' attitudes towards mathematics, brought about by their experience with the GeoGebra course, played a significant role in advancing their cognitive domain, as noted in (McCulloch, Lovett, & Edgington, 2019).

The positive improvement in attitudes towards mathematics, resulting from the confidence gained through working with GeoGebra, enabled pre-service instructors to overcome cognitive limitations and improve their mathematical attitudes. This aligns with the conclusions drawn by Finnegan (2021) in their doctoral dissertation on "Perceived Variables Affecting Math Teachers' Technolo-

gical Self-Efficacy." Examination of individual accomplishments of the participants revealed progressive cognitive development among PSTs due to the positive shift in their initial attitudes towards mathematics.

The data analysis also shows that while utilizing GeoGebra is thought to be a significant contributor to the observed change in affective and behavioral attitudes, it has a moderate-to-low impact on the improvement of the cognitive aspect. The findings of Haciomeroglu et al. (2009), who repeated this finding in a well-known study focusing on the participants' cognitive component, are exactly in line with the preceding. The results also show that it significantly improved performance on activities with a low to moderate degree of complexity, but tended to have less of an impact on complex tasks.

Most PSTs demonstrated critical thinking abilities, persistence, accuracy and rigor, autonomy, and systematization while using GeoGebra in a majority of sessions. The participants handled the tasks given to them by the software by using it (GeoGebra tasks). The prior is completely consistent with the claims made in the pedagogy book "Digital Active Methodologies for Educative Learning Management" by (Gigon, 2022). In contrast to the aforementioned attitudes, only a small number of PSTs scored highly on the change in flexibility of thought and creativity, but most of them did not score much higher.

The primary factor that influenced a change in mathematical attitudes among pre-service teachers (PSTs) was effective engagement with GeoGebra. The analysis highlights specific features and advantages of the software, coupled with the participants' increasing confidence in using GeoGebra for math-related activities. This finding aligns with previous studies such as (Turner et al., 2012; Thibaut et al., 2018; Beswick & Fraser, 2019).

Furthermore, the GeoGebra software proved helpful to some PSTs in adopting systematic learning strategies. This finding is supported by the research conducted by Fitriati, Rosli, and Iksan (2022), which confirms the earlier finding and also reveals that GeoGebra software contributed to the improvement of PSTs' flexibility of thought and creativity, albeit potentially indirectly for the latter aspect. This finding diverges from the results of Tunjera and Chigona (2020), who identified a strong and direct connection between flexibility of thought and creativity. However, the findings of this study are consistent and in line with (Letwinsky, 2017; Beswick & Fraser, 2019; Wilson, Hall, & Mulder, 2022: p. 17), despite potential contradictions with other studies in the same domain, such as (Tunjera & Chigona, 2020).

5. Conclusion

This study makes a significant contribution to the field by directly influencing people's belief systems. It fills a gap in the existing knowledge as it focuses on a minority population residing in Northern Israel, which has been understudied. The rationale for this research lies in the scarcity of studies specifically targeting this minority, and the study's practical experimentation in a technologically ad-

vanced learning environment sets it apart from theoretical frameworks and assumptions. The findings, outcomes, methods, approaches, and procedures of this research hold relevance and potential benefits for various educational phases and contexts from scientific, educational, and pedagogical perspectives.

The general attitudes of the participating students toward teaching and studying with GeoGebra are covered in detail in this study. Before and after a GeoGebra course, pre-service math teachers have very positive feelings about using the program. The participants were separated into two subgroups: approximately 10% did not exhibit any significant improvements when using the recommended pedagogical software, and approximately 90% showed significant improvements in attitudes and perceptions when using the designated software.

Data analysis highlights the role of teamwork as the second most important component in fostering attitudes like self-assurance, adaptability, creativity, systematization, and communication skills, after the effect of the GeoGebra program. After using software and interacting with teacher-instructors, pre-service teachers' collaborative efforts rank third in importance for the development of thinking, reasoning, and argumentation skills. The majority of participants show notable improvements in the affective and behavioral domains, but the cognitive domain shows no discernible change. Combining GeoGebra with traditional education is fun and interesting, and it produces favorable results on both a cognitive and attitude level. The three cycles of the research yield both professional and personal improvement, making the time and effort spent on planning, organizing, and carrying out the study worthwhile.

Important recommendations for teachers using GeoGebra in the classroom are made by this study. It is imperative that collaborative teamwork be emphasized in order to help pre-service teachers build critical abilities. To maximize the advantages of GeoGebra, teacher-instructor relations should be optimized, especially when it comes to directing group projects. Customized interventions might be required for the small percentage of participants who showed no discernible progress. The study emphasizes how crucial it is to continue conducting research in technologically sophisticated learning environments in order to promote the development of novel strategies that combine theory and practice for the best possible educational results. In order to ensure the ongoing development of efficient teaching techniques, future directions should involve broadening and improving existing strategies to serve a variety of educational environments and groups.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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