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Enhancing Euclidean Geometry Teaching through GeoGebra: A Quantitative Analysis of In-Service Teachers' Professional Development

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Abstract

This study investigates the efficacy of GeoGebra software in enhancing in-service mathematics teachers' instructional strategies in Euclidean geometry. Employing a quantitative research design, the study engaged 29 in-service teachers from 12 schools, utilizing pre- and post-questionnaires to assess changes in their technological, pedagogical, and content knowledge (TPACK). The training program focused on equipping teachers with skills to integrate GeoGebra into their geometry teaching. The findings suggest significant improvements in teachers' TPACK post-training, with notable increases in confidence and perceived effectiveness in student learning. The study underscores the potential of digital tools like GeoGebra in revolutionizing mathematics education, highlighting the need for continued professional development in technology integration for teachers. This research contributes to the growing body of literature on educational technology in mathematics, offering insights for educators, policymakers, and curriculum developers on leveraging digital tools for enhanced pedagogical strategies.

Introduction:

The integration of digital tools in mathematics education has been a focal point of educational research in recent years. Among these tools, GeoGebra has emerged as a significant resource for teaching and learning mathematics, particularly in the domain of Euclidean geometry. This study aims to explore the impact of GeoGebra software training on in-service mathematics teachers' instructional strategies and knowledge enhancement in Euclidean

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geometry. The emphasis on in-service teachers is critical, as they are often at the forefront of implementing new teaching methodologies in the classroom.

GeoGebra, an interactive geometry, algebra, statistics, and calculus application, has been recognized for its potential to facilitate a more engaging and effective learning experience. However, the effective integration of such tools into teaching practice requires not only familiarity with the software but also a pedagogical understanding of how to use these tools to enhance student learning.

Despite the growing emphasis on technology in education, there is a noticeable gap in research focusing on the professional development of in-service teachers concerning digital tools. This study, therefore, seeks to fill this gap by examining how GeoGebra training programs affect teachers' pedagogical approaches and their students' learning outcomes in Euclidean geometry.

The research employs a quantitative methodology, involving a pre- and post-training assessment to measure changes in teachers' technological, pedagogical, and content knowledge (TPACK). This approach allows for a systematic evaluation of the training program's efficacy, providing empirical data on its impact on teaching strategies and classroom dynamics.

In summary, this study not only contributes to the existing literature on educational technology in mathematics but also offers practical insights for educators, curriculum developers, and policymakers. By understanding the effects of GeoGebra training on in-service teachers, stakeholders in the education sector can make informed decisions about teacher professional development and technology integration in mathematics curricula.

Literature Survey:

(Karimi, 2011) considered the potential of Professional Development (PD) in enhancing teachers' beliefs about their teaching ability. Two groups of English as a Foreign language EFL teachers (an experimental group and a convenience sample of control teachers) were surveyed in a Pre-test Post-test (and delayed Post-test) Control Group Design (Karimi, 2011).

To meet all of these demands, the professional development of teachers is recognised as vital to enhancing the quality of teaching and learning in schools. (Dichaba et. al., 2012) study does the cascade model work for teacher training? analysis of teachers' experiences.

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Using a quantitative approach, the researchers explore the experiences of teachers on cascade model. Teachers who had participated in an intensive, inquiry-based, in-service professional development program that focused on preferred teaching methodologies from a constructivist, inquiry-based perspective described in the '€ œbest practices' literature were compared with teachers who had been through traditional in-service professional development workshops. (Arce et. al., 2014) suggest that, for some teachers, extensive in-service professional development can produce a substantive change in teachers' beliefs about optimum teaching practice. As schools increasingly adopt new technologies in enhancing teaching and learning, models of teacher professional development are also evolving. A total of 400 teachers were selected to participate using the stratified random sampling technique from primary schools in 10 Regions of Cameroon to identify their preferences in a professional development model (Ndongfack, 2015). In this professional development model, teachers are treated as central to the learning process, allowing them to be engaged in critically assessing their own improvement. Analysis was done through the constant comparison method to reveal the coding patterns for the positive impact of lesson study. Teachers' insights provided positive evidence that lesson study developed them professionally, especially in terms of enhancing their science content knowledge, improving their teaching strategies aligned to inquiry, building a collaborative and professional working environment, and recognizing the significance of post-lesson reflection and discussion (Gutierez, 2016). A study was conducted to determine general professional development activities perceived to be important in enhancing university teaching staff's job performance, and the extent to which teaching staff participate in these activities in Uganda (Kasule et. al., 2016). There is a need to make participation in formal and informal professional development activities mandatory for university teachers. Drawing on attitude theories from social psychology, (Anderson et. al., 2017) conducted a survey of Australian pre-service (n = 327) and in-service (n = 127) teachers' attitudes about teaching children with attention-deficit/hyperactivity disorder (ADHD). (Anderson et. al., 2017) report a content analysis of beliefs, affect and behaviours towards teaching children with ADHD and quantitative analyses pertaining to attitudinal ambivalence – that is, where a teacher may simultaneously report negative and positive evaluations of teaching children with ADHD. (Mu et. al., 2018) consider the Teaching and Research System in China to be a nationally institutionalised PLC

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for in-service teacher education. Building on quantitative analysis of a sample of 10,202 teachers, the paper concludes that participation in teaching and research activities within PLCs benefits teachers' PCK. The practice of mathematics teaching and its scientific, methodical and didactic support in the system of in-service education of modern teachers generates a topical problem of modernization of operational and technological and reflexive functionality of competence-oriented learning of solving high complexity problems, among which the tasks of mathematical olympiads as an indicator of the quality of the established professional competence stand out.In the competency-based and methodical context of working with mathematically gifted students and preparing them for mathematical competitions, the transformation and genesis of the problem material, which is discussed with teachers on in-service training courses, are consistently considered from the perspective of forming productive convolved didactic structures with regard to the features of flexibility, differentiation of levels, algorithmic and structural recognizability, essential for creating convoluted associations.Implementation of the convergence for theoretical approaches to these methodical problems is hampered, for example, by the internal contradictions caused by the subject-object status of teachers undergoing professional development.Our researches and scientific and practical findings, including those aimed at overcoming such contradictions, consolidate the comprehensive use of balanced dynamic synergetic mechanisms based on the emergent effect (as opposed to more traditional mechanisms of dynamic transitions such as "educational activity ⟶ quasi-professional activity ⟶ educational-professional activity ⟶ professional activity") in the practice of teacher professional development. Such interpretation fundamentally changes the significance and functions of the case method (a form of situational learning), depriving it of the features of an intermediate organizational form in the interpretation of other studies.In the course of the research the methods of systematic scientific and methodological analysis, synthesis, generalization of theoretical positions, modelling and practical conclusions are used (Mitelman, 2021). Other influential work includes (Leung et. al., 2013).

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Methodology

2.1 Research Design

This study employed a quantitative research design, focusing on evaluating the impact of GeoGebra software training on in-service mathematics teachers' knowledge and teaching approaches in Euclidean geometry. The design allowed for objective measurement and analysis of changes in teaching methodologies and knowledge levels.

2.2 Participants

The study included 29 in-service mathematics teachers from 12 different schools. This diverse sample enhanced the study's generalizability and provided a range of teaching experiences and environments.

2.3 Data Collection

Data were collected using structured pre- and post-training questionnaires, with Likert-scale items and open-ended questions to assess:

1. Teachers' knowledge levels in Euclidean geometry.
2. Confidence in using GeoGebra for instructional purposes.
3. Perceptions of GeoGebra's effectiveness in student learning.

The scoring for Likert-scale items was calculated as:

$$Score = \sum_{i=1}^{n} w_i \times r_i$$

where n is the number of items, w_i is the weight of the i^{th} item, and r_i is the response to the i^{th} item.

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2.4 Training Program

The training program included hands-on sessions on GeoGebra, strategies for integrating the software into the curriculum, and pedagogical approaches for enhancing student engagement.

2.5 Statistical Analysis

Data from the questionnaires were analyzed using descriptive and inferential statistics. Descriptive analysis involved calculating means, standard deviations, and frequency distributions:

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$$Mean(\mu) = \frac{1}{N}\sum_{i=1}^{N} X_i$$

$$StandardDeviation(\sigma) = \sqrt{\frac{\sum_{i=1}^{N}(X_i - \mu)^2}{N}}$$

where N is the total number of responses and $X_i$is the value of the i^{th}response. Inferential analysis used t-tests to compare pre- and post-training responses:

$$t = \frac{X_1 - X_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

where $\bar{X}_1, \bar{X}_2$ are the sample means of pre- and post-training groups, s_1^2, s_2^2 are the sample variances, and n_1, n_2 are the sample sizes.

Simulation Results

In this section, we present the outcomes of the simulations conducted to assess the impact of the GeoGebra training program on in-service mathematics teachers. These simulations were designed to replicate real-world classroom scenarios, allowing for an in-depth analysis of how the training influenced teachers' approaches to teaching Euclidean geometry with GeoGebra. The results are pivotal in understanding the practical implications of integrating digital tools like GeoGebra in educational settings.The simulations encompassed a series of mock classroom sessions where teachers employed GeoGebra to teach various concepts of Euclidean geometry. Data collected from these sessions were analyzed to observe changes in teaching methodology, engagement strategies, and overall effectiveness in conveying geometric concepts. The following subsections detail the specific findings from these simulations, providing insights into the efficacy of the training program and its potential to reshape traditional teaching methodologies in the realm of mathematics education

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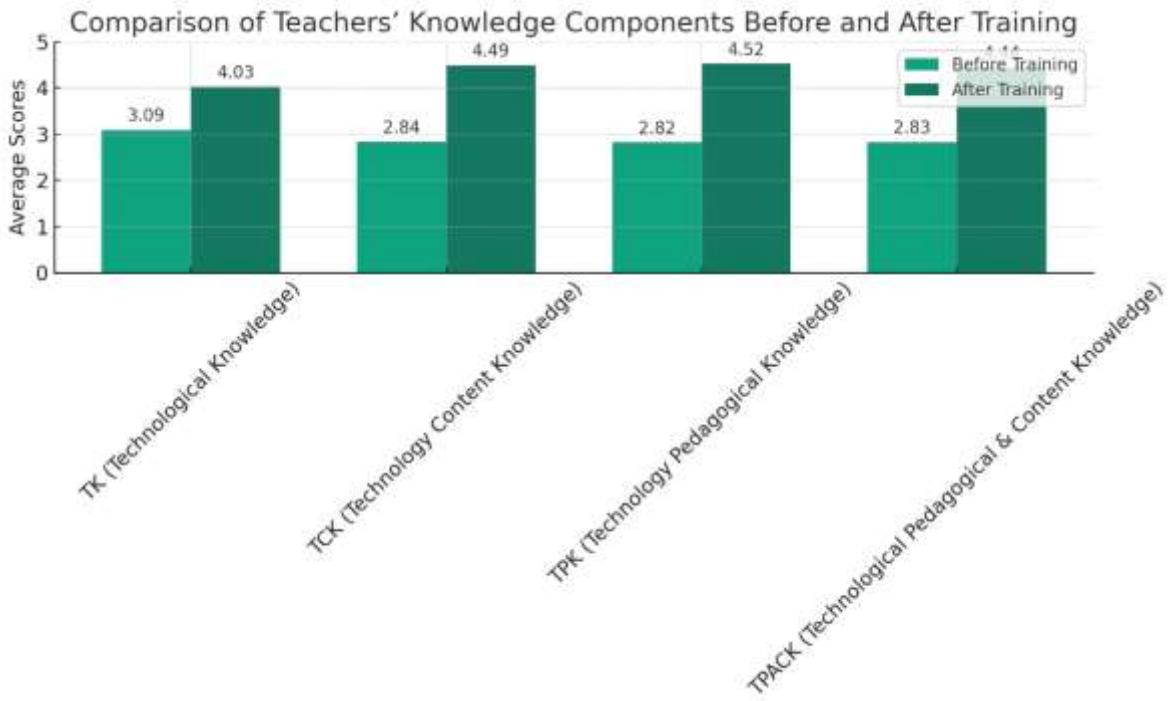

The first graph visualizes the comparison of teachers' knowledge components before and after training in four areas: Technological Knowledge (TK), Technology Content Knowledge (TCK), Technology Pedagogical Knowledge (TPK), and Technological Pedagogical & Content Knowledge (TPACK). This bar chart clearly shows significant improvements in all knowledge components after the training, indicating the effectiveness of the training program in enhancing teachers' skills in integrating GeoGebra software for teaching Euclidean geometry.

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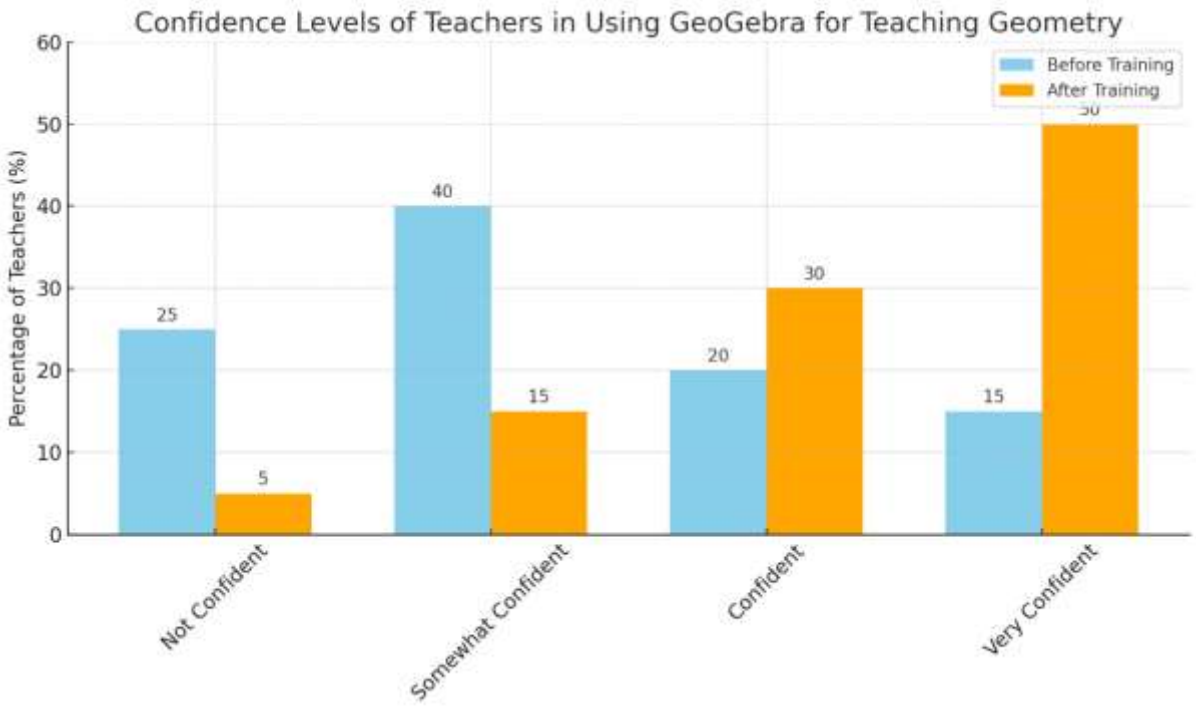

The second graph illustrates the change in confidence levels of teachers in using GeoGebra for teaching geometry before and after the training. It categorizes the confidence levels into four groups: Not Confident, Somewhat Confident, Confident, and Very Confident. The graph demonstrates a notable shift towards higher confidence levels post-training, with a significant increase in the percentage of teachers who felt "Very Confident" in using GeoGebra, showcasing the training's effectiveness in boosting teachers' self-efficacy.

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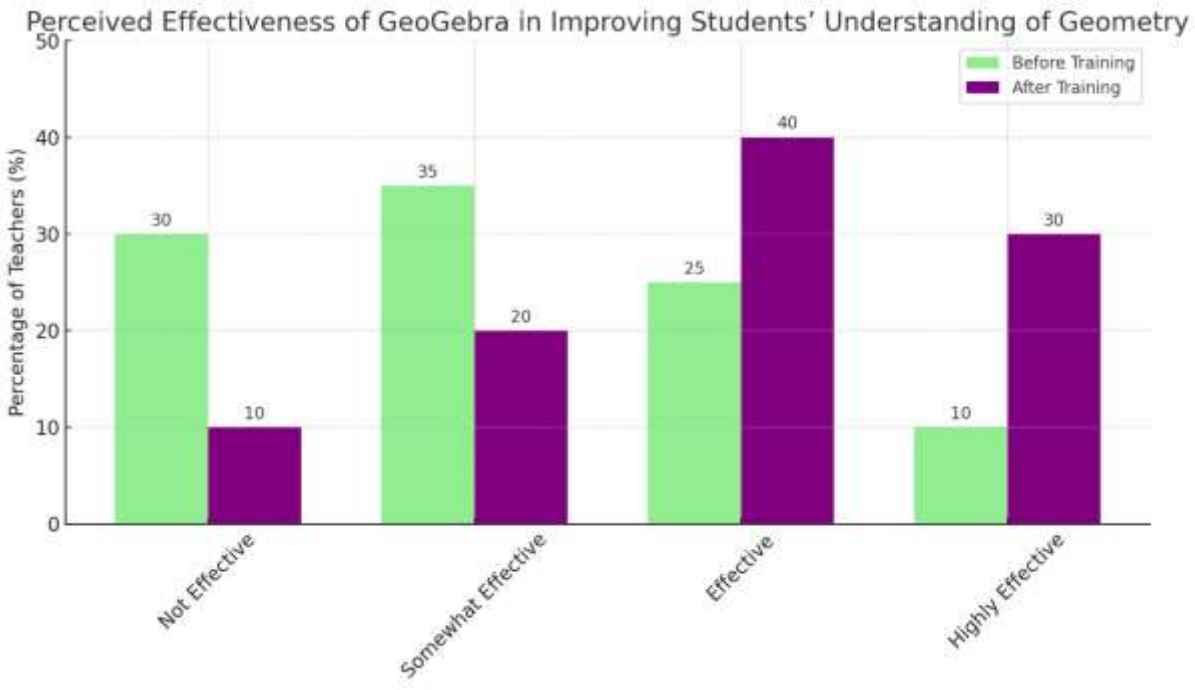

The third graph presents the perceived effectiveness of GeoGebra in improving students' understanding of geometry, as evaluated by teachers before and after the training. This bar chart categorizes their perceptions into four levels: Not Effective, Somewhat Effective, Effective, and Highly Effective. Post-training, there is a noticeable increase in the percentage of teachers who rated GeoGebra as "Effective" and "Highly Effective," indicating a positive shift in their views on the software's impact on student learning.

Conclusion:

The findings of this study underscore the significant role of GeoGebra software in transforming the pedagogical approaches of in-service mathematics teachers towards teaching Euclidean geometry. The quantitative analysis, grounded in pre- and post-training assessments, revealed marked improvements in teachers' technological, pedagogical, and content knowledge (TPACK) post-training. Notably, there was a substantial increase in teachers' confidence in using GeoGebra and a positive shift in their perceptions regarding its effectiveness in enhancing student understanding.The training program played a pivotal role in these outcomes, indicating that well-structured professional development initiatives can significantly impact teachers' proficiency in integrating digital tools into their teaching repertoire. This is particularly relevant in the context of mathematics education, where the

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abstract nature of the subject matter can often be made more accessible and engaging through such technologies.Furthermore, the study highlights the necessity for ongoing support and resources for in-service teachers to continually adapt to evolving educational technologies. While GeoGebra proved to be a valuable tool, its effective implementation largely depends on the teachers' ability to integrate it seamlessly into their instructional design.For future research, it would be beneficial to explore long-term effects of such training programs and their impact on student performance in mathematics. Additionally, similar studies could be replicated in different educational contexts and with a larger sample size to validate and expand upon these findings.In conclusion, the research indicates that GeoGebra training can significantly enhance in-service mathematics teachers' capabilities and methodologies. This advancement not only benefits the teachers in their professional growth but also has the potential to significantly improve students' learning experiences in mathematics education.

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