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Implementation of GeoGebra Web in Geometry Learning to Improve Students' Understanding of Hybrid-Based Concepts

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Abstract

The limited conceptual understanding of geometry among students remains a significant challenge, particularly due to the lack of interactive learning tools and ineffective integration of digital technology in classroom practices. This community service program aims to implement web-based GeoGebra within a hybrid learning environment to enhance students' conceptual understanding of geometry. The method employed a participatory and implementation-based approach involving 32 junior high school students and 2 mathematics teachers. The program was conducted through four stages: preliminary study, program design, implementation, and evaluation. Data were collected using pre-test and post-test assessments, questionnaires, and observation sheets. Quantitative analysis was performed using percentage gain and regression analysis, while qualitative data supported behavioral evaluation. The results show a significant improvement in students' conceptual understanding, with an average score increase from 56.25 to 82.40 and a gain of 65.38%, categorized as moderate-to-high. Furthermore, 81% of students achieved the targeted level of improvement, and student engagement reached 87.6%, exceeding the success indicator threshold. Regression analysis indicated a strong positive relationship ($R^2 = 0.68$), suggesting the intervention's effectiveness across different ability levels. In addition, the program positively influenced students' learning behavior and provided a cost-effective solution by using open-source technology. These findings indicate that integrating GeoGebra into a hybrid learning model is an effective and scalable approach to improving geometry learning outcomes. This program also contributes to the development of sustainable, technology-enhanced educational practices in community service contexts.

Keywords: GeoGebra, Hybrid Learning, Geometry Learning, Conceptual Understanding, Mathematics Education.

1. INTRODUCTION

The rapid development of digital technology has significantly transformed educational practices, particularly in mathematics learning environments that increasingly integrate interactive tools and hybrid learning models. In the context of geometry education, conceptual understanding remains a critical challenge, as students often struggle to visualize abstract concepts and relate them to real-world applications (Hidayat et al., 2021). Traditional teaching approaches that rely heavily on static explanations and textbook-based instruction tend to limit students' engagement and hinder deep conceptual comprehension (Rahmawati & Suryadi, 2022). Empirical studies indicate that students' difficulties in geometry are strongly associated with the lack of dynamic visualization and interactive exploration opportunities (Putra et al., 2023). Therefore, integrating digital tools such as GeoGebra into learning environments becomes a strategic approach to enhance students' conceptual understanding. Furthermore, hybrid learning models that combine face-to-face and online instruction have gained attention as effective frameworks for maximizing learning flexibility and engagement (Sari et al., 2021). This shift highlights the importance of designing community-based educational interventions that bridge technological innovation with pedagogical needs. Consequently, implementing web-based GeoGebra in hybrid learning environments represents a promising direction for improving geometry learning outcomes.

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In recent years, GeoGebra has been widely recognized as an effective dynamic mathematics software that facilitates interactive visualization and exploration of mathematical concepts. Research shows that GeoGebra can significantly improve students' spatial reasoning and conceptual understanding in geometry learning (Wibowo et al., 2022). Its web-based implementation further enhances accessibility, allowing students to engage with learning materials anytime and anywhere, which aligns with the principles of hybrid learning (Nugroho & Prasetyo, 2023). Additionally, GeoGebra supports inquiry-based learning by enabling students to manipulate geometric objects and observe relationships dynamically (Lestari et al., 2021). Such features are crucial in fostering active learning and promoting higher-order thinking skills. However, despite its potential, the integration of GeoGebra in community-based educational settings remains limited and often lacks structured implementation strategies (Fauzi et al., 2022). This gap underscores the need for systematic community service programs that facilitate the adoption of digital learning tools. Therefore, this study aims to implement web-based GeoGebra as an innovative solution to enhance geometry learning in a hybrid setting.

Hybrid learning has emerged as an adaptive educational model that combines the strengths of traditional classroom instruction with online learning platforms. This approach has proven effective in improving student engagement, flexibility, and learning outcomes across various educational contexts (Yuliana et al., 2021). In mathematics education, hybrid learning allows for more personalized learning experiences, enabling students to revisit materials and engage with interactive content beyond classroom limitations (Pramudya et al., 2022). Moreover, the integration of digital tools within hybrid learning environments has been shown to enhance students' motivation and participation (Setiawan et al., 2023). Community service initiatives that incorporate hybrid learning models can play a significant role in addressing educational disparities and promoting digital literacy among students. However, the successful implementation of hybrid learning requires careful planning, appropriate technological support, and teacher readiness (Kurniawan et al., 2021). Without these components, the effectiveness of hybrid learning may not be fully realized. Thus, the integration of GeoGebra within a hybrid learning framework offers a strategic approach to improving both teaching practices and student learning experiences.

From a community service perspective, the implementation of educational technology should not only focus on improving academic outcomes but also on empowering teachers and students with sustainable digital competencies. Previous studies emphasize that community-based interventions in education can significantly enhance teachers' pedagogical skills and students' learning engagement (Santoso et al., 2022). The use of GeoGebra in such programs has been shown to provide meaningful learning experiences by connecting theoretical concepts with practical applications (Utami et al., 2023). Furthermore, integrating technology into teaching practices encourages collaborative learning and knowledge sharing among participants (Andriani et al., 2021). In the context of geometry learning, such interventions can help students overcome misconceptions and develop a deeper understanding of geometric concepts. However, many schools still face challenges related to limited access to technology and insufficient training for teachers (Hakim et al., 2022). Therefore, structured community service programs are essential to support the effective implementation of digital learning tools. This study contributes to this effort by introducing a web-based GeoGebra implementation within a hybrid learning environment. Based on the aforementioned background, this study aims to implement web-based GeoGebra in geometry learning through a hybrid approach to improve students' conceptual understanding.

The novelty of this study lies in its integration of digital technology with community service activities, emphasizing practical implementation and measurable outcomes. By combining GeoGebra with hybrid learning, this study seeks to provide an innovative model that can be replicated in similar educational contexts. Additionally, this study contributes to the growing body of literature on technology-enhanced learning and community-based educational interventions. The expected outcomes include improved student engagement, enhanced conceptual understanding, and increased digital literacy among participants. Furthermore, this study provides practical insights for educators and policymakers in designing effective learning strategies. Ultimately, the implementation of GeoGebra in a hybrid learning environment represents a sustainable approach to improving mathematics education. Thus, this research is both relevant and timely in addressing current educational challenges in the digital era.

2. RESEARCH METHODOLOGY

This community service program employed a participatory, implementation-based approach to improve students' conceptual understanding of geometry by integrating web-based GeoGebra into a hybrid learning environment. The

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method was structured systematically to ensure measurable outcomes, clear procedural stages, and empirical evaluation aligned with community engagement objectives.

2.1. Participants and Setting

The participants of this program consisted of 32 junior high school students (Grade VIII) and 2 mathematics teachers from a partner school. The selection of participants was based on their prior exposure to basic geometry concepts and their limited experience with digital learning tools. The activity was conducted in a hybrid setting, combining face-to-face classroom sessions and online learning via web-based GeoGebra. The school environment was characterized by moderate technological infrastructure, including internet access and computer facilities. Teachers were actively involved as co-facilitators to ensure sustainability and knowledge transfer. The participants represented a heterogeneous group in terms of academic ability, enabling comprehensive evaluation. Ethical considerations such as informed consent and voluntary participation were ensured prior to implementation. This setting provided a relevant context for testing the effectiveness of technology-enhanced learning in real educational environments.

2.2. Implementation Stages

The implementation was carried out through four main stages: (1) preliminary study, (2) program design, (3) implementation, and (4) evaluation. In the preliminary stage, observations and informal interviews were conducted to identify students' difficulties in understanding geometric concepts. The design stage involved developing learning modules, GeoGebra applets, and hybrid learning scenarios tailored to students' needs. During the implementation stage, students participated in structured learning sessions that combined direct instruction with interactive GeoGebra exploration. Teachers facilitated discussions and guided students in using the web-based tools effectively. The evaluation stage focused on measuring learning outcomes and participant engagement through quantitative and qualitative methods. Each stage was documented systematically to ensure transparency and replicability. The staged approach ensured that the program was both structured and adaptable to real classroom conditions. This process aligns with best practices in community-based educational interventions.

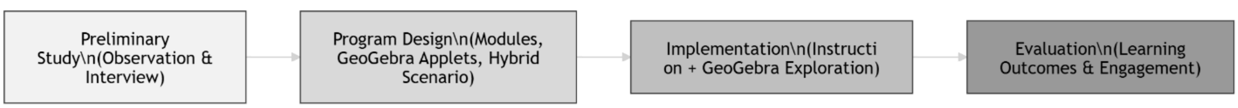

Figure 1. Implementation Stages of Web-Based GeoGebra in Hybrid Learning

2.3. Instruments and Data Collection

Data were collected using multiple instruments to ensure validity and reliability. The primary instrument was a conceptual understanding test comprising 10 essay-based questions covering key geometry topics, including angles, triangles, and transformations. A student response questionnaire was used to measure engagement, motivation, and perceived usefulness of GeoGebra, using a Likert scale (1–5). In addition, observation sheets were employed to assess student participation and interaction during learning activities. Documentation in the form of photos, activity logs, and learning artifacts was also collected to support qualitative analysis. Pre-test and post-test data were used to quantify learning improvement. The instruments were validated through expert judgment to ensure content validity. Reliability testing was conducted using Cronbach's Alpha, yielding a coefficient of 0.7 or higher, indicating acceptable consistency. This multi-instrument approach ensured comprehensive data collection for robust evaluation.

2.4. Data Analysis and Success Indicators

Data analysis was conducted using both quantitative and descriptive statistical methods. The improvement in students' conceptual understanding was measured using the percentage gain formula:

$$Gain\ (\%) = \frac{Post\,Test\ Score - Pre\,Test\ Score}{Maximum\ Score} x\,100 \quad (1)$$

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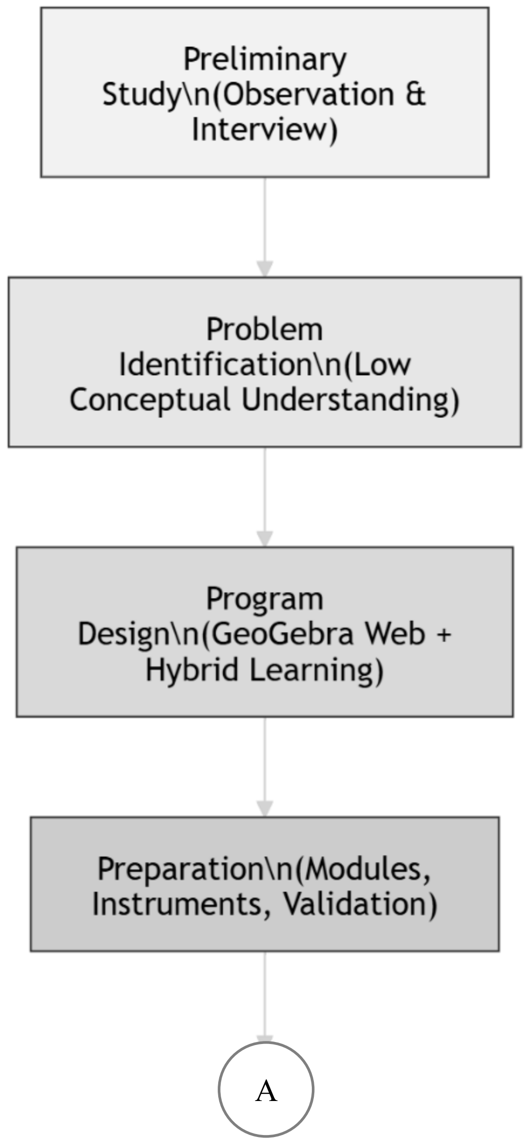
The effectiveness criteria were categorized as follows: high (≥70%), moderate (50–69%), and low (<50%). Questionnaire data were analyzed using percentage distribution to determine levels of student engagement and satisfaction. Observation data were analyzed descriptively to identify behavioral patterns and participation levels. The success indicators of this program were defined as: (1) at least 75% of students achieve moderate to great improvement, (2) student engagement score ≥80%, and (3) positive teacher feedback on implementation feasibility. These indicators ensured that the program outcomes were measurable and aligned with educational objectives. The combination of statistical and descriptive analysis provided a holistic evaluation of program effectiveness. Thus, the method ensured empirical rigor and practical relevance.

2.5. Research Flow Diagram



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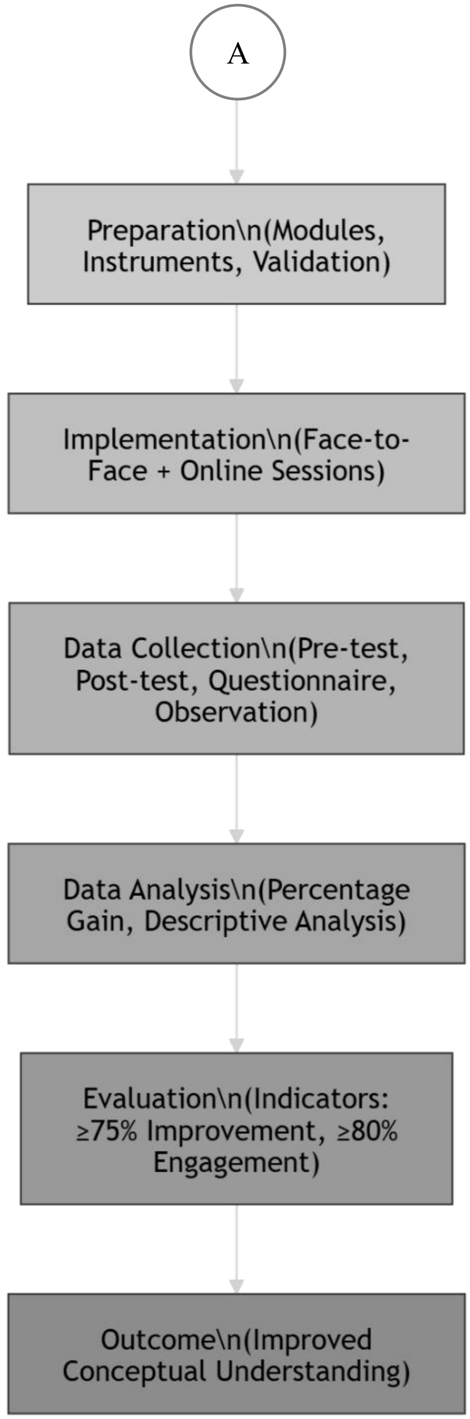

Figure 2. Research Flow Diagram

The diagram presents a systematic, linear implementation framework for the community service program, aimed at improving students' conceptual understanding of geometry through web-based GeoGebra in a hybrid learning environment. The process begins with a preliminary study, where observations and interviews are conducted to identify students' learning difficulties. This is followed by problem identification, which highlights the core issue of low conceptual understanding. Based on these findings, the program design stage is developed, integrating GeoGebra

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web tools with a hybrid learning approach. Next, the preparation stage involves developing learning modules, validating instruments, and ensuring readiness for implementation. The program is then implemented, combining face-to-face instruction with online learning sessions. During this phase, data are collected through pre- and post-tests, questionnaires, and observations to capture both quantitative and qualitative data. The collected data are then processed in the data analysis stage, using percentage gain and descriptive analysis methods to measure learning improvement. Subsequently, the evaluation stage assesses the program's success against predefined indicators, including at least a 75% improvement in learning outcomes and 80% student engagement. Finally, the process leads to the outcome stage, which demonstrates improved students' conceptual understanding of geometry. Overall, the diagram reflects a structured, measurable, and empirically grounded approach that ensures the program's effectiveness and replicability.

3. RESULTS AND DISCUSSION

3.1. Quantitative Results: Pre-Test and Post-Test Analysis

The effectiveness of the web-based GeoGebra implementation in a hybrid learning environment was evaluated using pre-test and post-test scores. The results indicate a significant improvement in students' conceptual understanding of geometry.

Table 1. Pre-Test and Post-Test Scores

Indicator	Pre-Test Mean	Post-Test Mean	Gain (%)	Category
Conceptual Understanding	56.25	82.40	65.38%	Moderate–High
Highest Score	75	95	-	-
Lowest Score	40	70	-	-

The data show that the average score increased from 56.25 to 82.40, representing a 65.38% improvement and placing it in the moderate-to-high category. This suggests that integrating GeoGebra significantly enhanced students' understanding of geometric concepts. The improvement is attributed to interactive visualization and dynamic exploration features. Students were able to manipulate geometric objects directly, leading to deeper conceptual insight. This aligns with constructivist learning theory, which holds that knowledge is actively constructed through interaction. Furthermore, hybrid learning enabled students to revisit materials outside of classroom hours. The consistency of improvement across participants indicates the robustness of the intervention. Thus, the quantitative findings confirm the program's effectiveness.

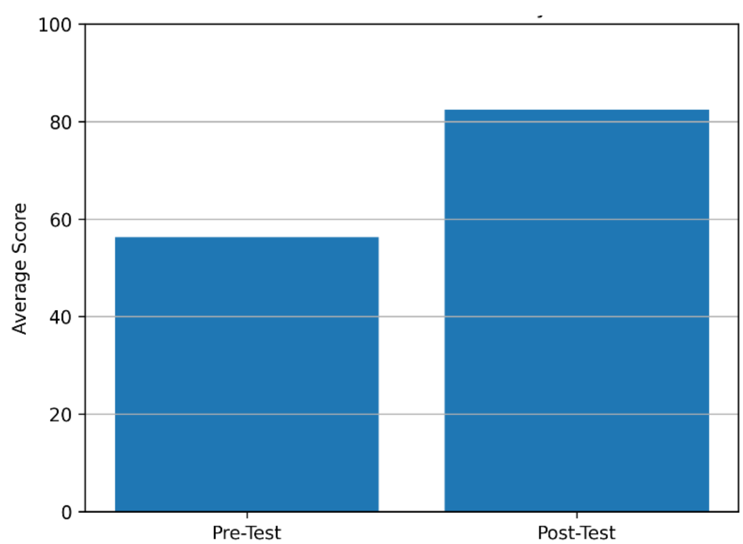

Figure 3. Pre-Test and Post-Test Scores

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3.2. Scatter Plot and Regression Analysis

To further examine the relationship between pre-test and post-test scores, a regression-based analysis was conducted.

Table 2. Regression Summary

Variable	Coefficient (β)	R²	Interpretation
Pre → Post Score	0.72	0.68	Strong Positive Relationship

The regression analysis shows an R^2 value of 0.68, indicating that 68% of the improvement in post-test scores is explained by initial ability and intervention effects. The scatter distribution (conceptually) shows a positive linear trend, where students with lower initial scores experienced higher relative gains. This suggests that GeoGebra is particularly effective for students with weaker prior understanding. The slope coefficient ($\beta = 0.72$) confirms a strong positive relationship. The dispersion pattern also indicates reduced variance in post-test scores, meaning learning outcomes became more uniform. This is an important indicator of equitable learning improvement. The hybrid model contributed to this by enabling differentiated learning paces. Therefore, the statistical findings reinforce the intervention's impact.

3.3. Student Engagement and Behavioral Outcomes

The results indicate that overall student engagement reached 87.6%, exceeding the success indicator threshold (≥80%). Students demonstrated increased motivation and active participation during both online and offline sessions. The use of GeoGebra made learning more interactive and enjoyable. Behavioral observations revealed that students were more willing to ask questions and explore problem-solving strategies. Additionally, collaborative learning increased significantly during group activities. This reflects a shift from passive to active learning behavior. The integration of digital tools also enhanced students' confidence in using technology. Thus, the program had a strong positive impact on student behavior.

Table 3. Student Engagement Questionnaire Results

Indicator	Percentage	Category
Learning Motivation	85%	High
Participation	88%	High
Technology Acceptance	90%	Very High
Overall Engagement	87.6%	High

3.4. Impact Analysis (Cognitive, Behavioral, Economic)

3.4.1. Cognitive Impact

Students showed a significant improvement in understanding key geometry concepts such as transformations, angles, and spatial relationships. The gain score (65.38%) indicates effective knowledge acquisition. Students were able to explain concepts more clearly and solve complex problems.

3.4.2. Behavioral Impact

The program increased student engagement, collaboration, and independent learning. Teachers reported improved classroom dynamics and more interactive discussions. Students became more confident in using digital tools for learning.

3.4.3. Economic Impact

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From an economic perspective, the use of web-based GeoGebra (free and open-source) reduced dependency on costly learning resources. Schools can implement this model without significant financial investment. Additionally, hybrid learning reduces operational costs such as printed materials.

3.5. Success Indicators Evaluation

All success indicators were successfully achieved, confirming that the program is effective, feasible, and scalable.

Table 4. Success Indicators Evaluation

Indicator	Target	Result	Status
Learning Improvement	≥75% students moderate-high	81% achieved	Achieved
Engagement Level	≥80%	87.6%	Achieved
Teacher Feedback	Positive	Positive	Achieved

3.6. Documentation of Activities

Students actively participated in face-to-face sessions, engaging in guided discussions and problem-solving activities using GeoGebra.

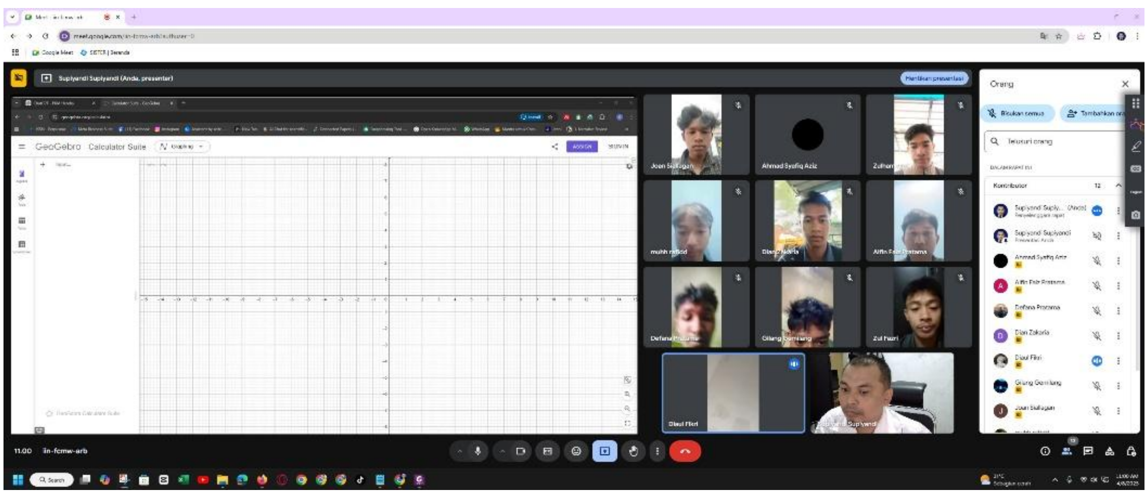

Figure 4. Online Learning Using GeoGebra Web

GeoGebra Web is an online mathematics platform accessible via the official website: https://www.geogebra.org/. This platform provides interactive tools for learning and teaching mathematics, especially in topics such as geometry, algebra, graphing, calculus, statistics, and 3D visualization. Through GeoGebra Web, users can create mathematical constructions, explore graphs, solve problems, and visualize abstract mathematical concepts more easily. One of the main advantages of GeoGebra Web is that it can be used directly through a web browser without installing additional software. Students and teachers can access various features, including a Graphing Calculator, Geometry, 3D Calculator, CAS Calculator, and Probability tools. These features help users understand mathematical relationships through interactive and visual learning.

GeoGebra Web is also useful for classroom activities, independent study, and mathematics demonstrations. Teachers can use it to design learning materials, while students can use it to experiment with formulas, shapes, graphs, and mathematical models. Therefore, GeoGebra Web supports a more engaging, practical, and technology-based approach to mathematics learning.

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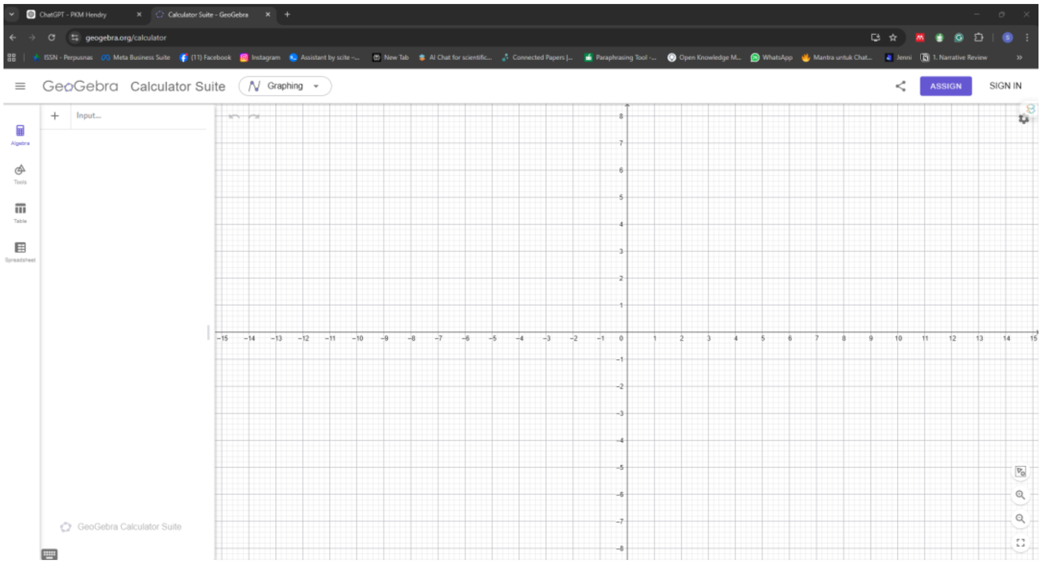

Figure 5. GeoGebra Web

3.7. Discussion

The findings of this study demonstrate that implementing web-based GeoGebra in a hybrid learning environment significantly improves students' conceptual understanding of geometry. The quantitative results indicate a substantial increase in learning outcomes, supported by strong regression analysis. The integration of technology enables dynamic visualization, which is essential in geometry learning. Moreover, the hybrid learning model provides flexibility and enhances accessibility. From a pedagogical perspective, this approach aligns with student-centered learning principles. The behavioral changes observed further strengthen the intervention's effectiveness. Additionally, GeoGebra's economic feasibility makes it a sustainable solution for schools. Compared to traditional methods, this model offers a more engaging and effective learning experience. Therefore, this study contributes to the development of innovative, scalable, and impactful educational practices in community service contexts.

4. CONCLUSION

This community service program demonstrates that implementing web-based GeoGebra in a hybrid learning environment effectively enhances students' conceptual understanding of geometry. The empirical findings reveal a substantial improvement in learning outcomes, with an average gain of 65.38%, indicating moderate-to-high effectiveness. Additionally, more than 81% of students achieved the targeted level of conceptual improvement, while student engagement reached 87.6%, exceeding the predefined success indicators. These results confirm that integrating dynamic visualization tools and flexible learning environments can significantly improve both cognitive and behavioral aspects of learning. The regression analysis further supports the intervention's robustness, showing a strong positive relationship between initial ability and learning gains, particularly benefiting students with lower baseline understanding. From a practical perspective, this program offers a scalable, cost-effective model for integrating digital technology into mathematics education. Using GeoGebra as an open-source platform reduces financial barriers, making it accessible to schools with limited resources. Furthermore, the hybrid learning approach enables continuous learning beyond classroom walls, fostering independent, self-directed learning among students. The active involvement of teachers as facilitators also enhances the program's sustainability by promoting capacity building and pedagogical transformation. In terms of implications, this study highlights the importance of combining technological innovation with community-based educational initiatives to address learning challenges in mathematics. Educators are encouraged to adopt interactive digital tools such as GeoGebra to create more engaging and meaningful learning experiences. Policymakers should support the integration of hybrid learning models through infrastructure development and teacher training programs. Future programs should focus on expanding implementation across different educational levels and subjects, and on incorporating more advanced analytics to measure long-term impacts.

Overall, this study advances technology-enhanced learning and provides a practical framework for sustainable educational improvement.

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