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Empowering Mathematics Teachers through Geogebra Training on Solids and Nets: A Community Engagement Approach

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Abstract

Integrating technology into mathematics instruction requires equipping teachers with both technical skills and pedagogical insight. As part of a broader community engagement initiative, a GeoGebra training program was designed to support mathematics teachers through dynamic modeling. This study focuses on a specific module in which participants constructed 3D cuboids and designed nets of square pyramids using GeoGebra. The training emphasized features such as sliders, surface area, volume visualization and nets to enhance conceptual understanding. Participants were guided through step-by-step demonstrations and documented their modeling processes in structured worksheets. To evaluate the impact of the training, pre-test and post-test were conducted to assess improvements in GeoGebra proficiency, along with worksheets that documented each participant's process and approach. The results revealed significant gains in both teacher's technical competence and their confidence in applying GeoGebra in classroom instruction. This study highlights how focused modules within a community-based training program can meaningfully support teachers in integrating dynamic mathematics tools into classroom instruction.

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Introduction

The digital era has made the integration of technology into the teaching and learning process increasingly essential. Digital tools such as GeoGebra serve as powerful supports in mathematics education by enhancing both visualization and conceptual understanding. GeoGebra, a dynamic mathematics software, enables users to explore and interact with mathematical objects including geometry, algebra, and calculus through an intuitive and interactive interface (Hohenwarter et al., 2004). With its web-based nature, GeoGebra remains easily accessible for both teachers and students, offering practical applications in various classroom settings (Arbain & Shukor, 2015). Pre-service teachers recognize GeoGebra as an effective medium to enhance their teaching methodologies, reinforcing their capacities as educators (Assadi & Crețu, 2023). Their familiarity with this software aids in teaching mathematical concepts while preparing them to leverage technology in fostering a more interactive and student-centered classroom environment (Furner, 2024). Studies indicate that the applications of GeoGebra across various educational curriculum frameworks significantly leverage its capabilities to engage students with complex mathematical ideas (Martín-Cudero et al., 2024).

Furthermore, 21st-century education requires students to develop a wide range of skills, including critical thinking, problem-solving, creativity, collaboration, and technological literacy (Dewi et al., 2023). In this context, the integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education plays a pivotal role. STEAM represents an innovative and interdisciplinary approach that equips students with the essential skills needed to thrive in an increasingly interconnected and dynamic global workforce. By merging these diverse fields, STEAM education not only enhances students' cognitive abilities but also nurtures their creativity, critical thinking, collaboration, and communication skills (Ismiati, 2024).

Recognizing these needs, teacher training programs focused on practical technology integration become crucial. Professional development opportunities, such as workshops or hands-on training sessions, empower teachers to confidently apply digital tools in their classrooms. When conducted within an established teacher community, such as the mathematics teacher working group (MGMP), these programs are often more impactful. These communities provide a platform for teachers to share experiences, collaborate, and receive peer support, thereby enhancing the effectiveness and sustainability of the training (Richit et al., 2024)

Meeting the demands of 21st-century education requires teachers to continuously update their pedagogical and technological skills (Saimon et al., 2024). The rapid development of digital tools challenges educators to adapt and innovate their teaching practices. Mathematics teachers, in particular, face the expectation of mastering content knowledge while also building competence in using technology to support learning (Santos et al., 2025). This expectation aligns with the Technological Pedagogical Content Knowledge (TPACK) framework, which highlights the importance of integrating technology with pedagogy and subject matter for effective instructional strategies (Santos et al., 2025).

A community engagement approach in education emphasizes the collaborative relationship between teachers, students, parents, and the broader community, which is essential for fostering an effective learning environment. Community engagement extends to creating culturally responsive pedagogies. Othman and Ruslan emphasize the importance of community-based teacher education in fostering multicultural awareness among educators, enabling them to better serve diverse student populations (Othman & Ruslan, 2020). This understanding enriches the classroom experience and prepares teachers to engage effectively with various cultural backgrounds, fostering an inclusive educational environment.

To successfully implement a community engagement initiative aimed at strengthening mathematics teachers' capacity in using GeoGebra for teaching three-dimensional shapes and their nets, it is essential to understand the current landscape of GeoGebra's application in mathematics education and the associated professional development needs of teachers. Recent studies underscore the importance of training and support systems for teachers to effectively utilize GeoGebra in their classrooms. For example, Mokotjo and Mokhele emphasize that providing cognitive support for educators who may have apprehensions about using GeoGebra is crucial for its effective integration into the curriculum (Mokotjo & Mokhele, 2021). Similarly, Mokotjo highlights the necessity of aligning professional development programs with existing educational guidelines to ensure that teachers are well-equipped and motivated to adopt this technology (Mokotjo, 2023). The enhancement of teacher support mechanisms, including structured training and resources, can address common challenges faced in teaching mathematics with GeoGebra (Muslim et al., 2023).

Theoretical Framework

The theoretical framework that encompasses the concepts of the Zone of Proximal Development (ZPD) and Technological Pedagogical Content Knowledge (TPACK) particularly within the context of integrating technology like GeoGebra in teaching practices (Santos et al., 2025). Each of these frameworks elucidates significant dimensions of educational practice, contributing to a holistic understanding of how educators can effectively implement technology to facilitate meaningful student learning.

The Zone of Proximal Development (ZPD), a construct proposed by Vygotsky, reflects the space between what a learner can do independently and what they can accomplish with guidance or collaboration. In the context of mathematics education, GeoGebra serves as a tool that enables educators to bridge this gap. For example, when utilizing GeoGebra, teachers can provide scaffolded instruction, which is instrumental in helping students reach their learning potential (Muslim et al., 2023). It allows teachers to visualize students' thought processes in real time and offer tailored feedback, ensuring that each student receives the support necessary to progress within their ZPD (Horzum & Ünlü, 2017). Additionally, studies have highlighted that using GeoGebra enhances student understanding by allowing them to interact with mathematical concepts and promotes higher-order thinking skills (HOTS) through its capacity for dynamic visual learning and manipulation of mathematical objects (Misrom et al., 2020).

Technological Pedagogical Content Knowledge (TPACK) further enhances the conversation surrounding the use of GeoGebra in education. TPACK refers to the knowledge teachers need to integrate technology effectively into their teaching. It emphasizes the interplay between Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). This framework suggests that for teachers to effectively employ geo-scientific tools like GeoGebra, they must possess not only a sound understanding of mathematics but also pedagogical strategies that leverage technology to enhance student learning (Bueno et al., 2021). For instance, a teacher using GeoGebra to model geometric transformations engages students through interactive content that challenges their conceptual understanding, making mathematical relationships more accessible (Kllogjeri & Kllogjeri, 2015).

Research indicates that professional development programs aimed at enhancing teachers' TPACK have led to improved integration of GeoGebra in the classroom, consequently boosting students' mathematical comprehension and achievement (Bueno et al., 2021). By fostering a robust TPACK framework, educators can create a synergistic relationship between technology and pedagogy, thereby enriching the curriculum and enhancing student learning outcomes (Bayaga et al., 2019). The successful implementation of TPACK results in classrooms where technology serves as an enabling tool rather than a barrier to effective teaching. Thus, TPACK stands as a vital framework in the discussion of educational innovation, particularly in the context of mathematics teaching with GeoGebra.

The intersection of ZPD and TPACK presents a comprehensive framework for understanding how technology like GeoGebra can be effectively integrated into mathematics education. Teachers equipped with a strong TPACK are poised to create learning experiences that operate within each student's ZPD; they can introduce innovative technological solutions that fosters engagement and leads to mastery of mathematical concepts (Olsson, 2019). This cycle of adopting technology, participating in professional development to enhance TPACK, and utilizing knowledge of ZPD ultimately creates a fertile ground for effective learning outcomes in mathematics (Seloane et al., 2023)

Method

This study was conducted as part of a professional development initiative targeting junior secondary school mathematics teachers in Bandung, Indonesia. The primary objective of the project was to empower teachers to integrate accessible digital technologies, specifically the GeoGebra software and STEAM (Science, Technology, Engineering, Arts, and Mathematics) education principles into their classroom practices. By doing so, the project sought to enhance the quality of mathematics instruction and promote more innovative, technology-based learning experiences for students. The training commenced with an opening session attended by both teachers and facilitators, setting the stage for collaborative and engaging learning throughout the program (see Figure 1).

Figure 1. Opening session of GeoGebra training

The training was designed as a face-to-face program and was carried out at one of the participating schools in Bandung on May 7, 2025. The implementation of the training followed a structured format consisting of six sequential phases: (1) Pre-Test, aimed at assessing the initial knowledge of participants regarding Geogebra; (2) Presentation of Key Concepts and Materials by Lecturer; (3) Introduction to GeoGebra and Guided Steps for Educational Media Development; (4) Group-based Practical Sessions, during which participants collaboratively engaged in creating digital learning media using GeoGebra; (5) Presentation of Developed Media, allowing each group to demonstrate and reflect upon their work; and (6) Post-Test and Overall Training Evaluation, which measured learning gains and collected feedback for further improvement.

The selection and participation of teachers in the training were entirely voluntary. Recruitment was facilitated through collaboration with the Mathematics Subject Teacher Forum (MGMP) for MTs (Madrasah Tsanawiyah) in Bandung City. The process began by obtaining formal approval from school principals, followed by direct outreach to mathematics teachers at the respective schools that expressed interest. Throughout the training, participants were introduced to the basic and intermediate functionalities of the GeoGebra Classic platform. Practical sessions emphasized the use of GeoGebra's dynamic geometry tools for constructing three-dimensional objects such as rectangular prisms and designing nets of pyramids. These hands-on activities were intended to build teachers' confidence in using the software as a pedagogical tool and to encourage the application of STEAM-oriented learning strategies in real classroom contexts.

Research Approach

The present study adopted a qualitative Community Engagement Approach. This approach focuses on building meaningful collaborations between researchers and community members, in this case, mathematics teachers, through active involvement in identifying challenges, co-designing interventions, and implementing practical solutions in real-world educational settings. Community engagement ensures that the perspectives and experiences of participants directly inform the design and implementation of educational innovations, thereby increasing their relevance, acceptance, and sustainability in the local context. This methodological choice is aligned with an increasing emphasis within higher education on community engagement as a transformative strategy to connect academic work with societal needs (Denham et al., 2024). The engagement of educators in community-based initiatives is seen as a critical step in bridging academic knowledge with classroom practice, especially when addressing the integration of educational technology within STEAM-oriented instruction.

Participants, data collection methods and data analysis

In this study, seven participants were actively involved in the practical implementation of GeoGebra, with a specific focus on geometry instruction. These participants were divided into two smaller groups based on the instructional topic. Three participants worked on developing learning materials related to rectangular prisms, while the other three focused on pyramid nets. Each group engaged in hands-on exploration using GeoGebra to design visual, interactive representations aligned with their assigned geometric concepts. The training intervention was co-designed and implemented onsite, and structured into six key stages: Pre-Test, Presentation of Concepts, Introduction to GeoGebra and Media Development Steps, Group-Based Practice Sessions, Media Presentation, and Post-Test with Evaluation.

To understand the effectiveness and impact of the training, data were collected using several qualitative instruments (Creswell & Creswell, 2023). These included teacher questionnaires, distributed after the training, to gather participants' perceptions and experiences, worksheets produced during group demonstrations involving the construction of 3D objects such as rectangular prisms and pyramid nets, and the results of pre-test and post-test assessments. These data sources provided insights into teachers' conceptual understanding, skill development, and the perceived relevance of the training content to their classroom practice. This combination of tools ensured a well-rounded understanding of the participants' learning process, while remaining consistent with the principles of community engagement, namely mutual participation, contextual responsiveness, and a focus on practical outcomes that benefit both educators and their students.

The data were analyzed using both descriptive and qualitative methods. Pre-test and post-test results were examined to capture changes in participants' knowledge and skills, while qualitative responses from the post-training questionnaires were thematically analyzed. The analysis revealed consistent themes related to participants' perceptions of the training, including the clarity of material delivery, facilitator effectiveness, and the alignment between the training content and classroom needs. Participants also highlighted the relevance of the instructional media, the practical value of the learning products, and the organized and communicative nature of the sessions. These findings provided a comprehensive understanding of how the training supported teachers' professional growth and instructional readiness.

In addition, the group worksheets, particularly those involving the construction of 3D mathematical models using GeoGebra, were reviewed to evaluate the application of conceptual understanding into practice. The analysis focused on the accuracy, creativity, and contextual relevance of the digital teaching media created by the participants. Together, these methods offered a comprehensive picture of the training's impact, combining measurable outcomes with reflective and practice-based evidence, in line with the principles of community engagement and participatory professional development.

Implementation of Community Engagement Approach

This study adopts a community engagement approach by organizing a professional training program on the use of GeoGebra for mathematics teachers in collaboration with the MGMP (Musyawarah Guru Mata Pelajaran) of Bandung City. Inspired by the model described by Denham et al., (2024), the implementation is designed to build reciprocal partnerships between university-based researchers and school-based educators. The training aligns with local educational needs and encourages mutual learning, in which teachers are not merely recipients of knowledge but co-creators in the instructional development process. During the workshop, participants actively explored GeoGebra tools through group practice (see Figure 2).

Figure 2. Participants practicing GeoGebra modeling

The program focuses on promoting academic community engagement by combining instructional innovation with practical relevance. Following the practices at Sam Houston State University, where community engagement is embedded into course design and faculty recognition, this initiative centers on improving classroom instruction through direct collaboration with teaching professionals. The engagement process includes needs assessment, training delivery, hands-on product development, and follow-up feedback from participants to ensure the training is aligned with school realities and professional expectations. Through this model, the study emphasizes the development of bridging and linking social capital between higher education and K-12 institutions.

Results

The pre-test and post-test scores demonstrated measurable improvement in participants' understanding and proficiency in using GeoGebra for mathematics instruction. Each assessment consisted of five multiple-choice questions designed to evaluate teachers' basic skills in using GeoGebra for 3D geometric modeling and visualization. The maximum score for each test was 5 points. As shown in Table 1, participants P1 to P4 were assigned to the rectangular prism group, while participants P5 to P7 worked on the pyramid net group during the hands-on media development session. All seven participants showed positive learning gains with increases ranging from +1 to +4 points. Most participants reached the maximum score of 5 in the post-test, indicating successful acquisition of core competencies related to dynamic geometry modeling.

Table 1. Comparison of Pre-test and Post-test Scores of Participants

Participant	Pre-Test	Post-Test	Description
P1	1	5	Improved
P2	1	5	Improved
P3	2	5	Improved
P4	2	5	Improved
P5	2	5	Improved
P6	0	2	Improved
P7	2	3	Improved

During the core activity of the training, participants worked in two focus groups: the Rectangular Prism group (P1–P4) and the Pyramid Net group (P5–P7). Each participant documented their work in a structured worksheet, which included a storyboard of their construction steps and links to their individual GeoGebra projects. Although tasks were completed in groups, every participant independently practiced and presented their models during the final session.

In the Rectangular Prism group, participants constructed 3D models of cuboids using GeoGebra's 3D graphics view. They began by creating a rectangular base using polygon tools, then extruded the base to form a prism, and added volume and surface area measurements. The group reflected that this model can help students explore how changes in side lengths affect surface area and volume, providing an interactive and visual means of conceptual understanding.

Meanwhile, the Pyramid Net group constructed square-based pyramids and visualized their nets using the *Net* tool in GeoGebra. The process included building a square base, selecting a peak point, generating a 3D pyramid using the *Pyramid* tool, and activating the unfolding function with a slider. This group highlighted that such visualization facilitates students' understanding of the component shapes that make up a pyramid, offering dynamic manipulation for better spatial reasoning.

Figure 3. Group presentation of GeoGebra models

Each group presented their completed 3D models and discussed classroom applications (see Figure 3). In addition to test results, qualitative responses from the post-training questionnaire (14 Likert-scale items and one open-ended item) were thematically analyzed. Most participants strongly agreed that the training was well-organized, the learning materials were suitable, and the facilitators were competent. Key aspects such as clarity of instruction, punctuality, and relevance to the school mathematics curriculum received average scores above 4.2 out of 5. Participants also noted that the media used (GeoGebra) was helpful in developing interactive learning materials.

Discussion

The results of this training program illustrate a positive shift in both the technical and pedagogical competencies of participating mathematics teachers. The significant improvement in pre-test and post-test scores confirms the effectiveness of the hands-on, guided approach employed throughout the training. Most participants reached or approached the maximum score in the post-test, indicating that the use of structured instruction and scaffolded tasks supported participants' development within their Zone of Proximal Development (ZPD).

Beyond the score gains, qualitative evidence from participant worksheets and reflections further supports the value of the training. Participants from both the Rectangular Prism and Pyramid Net groups were able to construct interactive 3D models using GeoGebra and articulated clear educational applications for their products. For instance, members of the Rectangular Prism group noted that their demonstration could be used to help students explore the relationship between the dimensions of a cuboid and its surface area and volume. This shows how digital modeling not only supports visualization but also enables inquiry-based learning (Thuneberg et al., 2018).

Similarly, participants in the Pyramid Net group emphasized that the dynamic unfolding of 3D objects into their nets through the GeoGebra interface helped clarify the connection between solid figures and their constituent plane shapes. The ability to manipulate sliders to fold and unfold the pyramid provided an engaging and intuitive learning experience, aligning well with student-centered instructional strategies. Likewise, members of the Rectangular Prism group noted that GeoGebra's dynamic features enabled students to receive immediate feedback and explore multiple solution paths, particularly when examining how dimensional changes influence surface area and volume (Mollakuqe & Mollakuqe, 2025).

These observations demonstrate how the training successfully promoted Technological Pedagogical Content Knowledge (TPACK). Teachers were not only introduced to the technological affordances of GeoGebra (TK) but also encouraged to integrate it meaningfully with content (geometry) and pedagogy (constructivist teaching strategies). By allowing teachers to co-design media within a collaborative setting, the training embodied the spirit of community engagement, where participants are active agents in their own professional development. Additionally, the program addressed contextual realities by embedding the training within the existing teacher community (MGMP) and leveraging peer collaboration to foster sustainability. This aligns with findings by Denham et al. (2024), which emphasize that faculty and educator motivation to participate in community-engaged initiatives is driven by their desire to produce meaningful, classroom-relevant impacts. The collaborative nature of this program, combined with the practical outputs it produced, contributes to the broader goals of equity, accessibility, and responsiveness in professional teacher training.

Conclusion

The implementation of GeoGebra training through a community engagement approach proved to be a valuable strategy for strengthening teachers' skills in both technology use and pedagogical design. Participants showed clear improvement in their ability to construct and apply dynamic geometry models, supported by meaningful reflections on how these tools could enhance classroom learning. The training not only improved their technical competence, but also encouraged them to think critically about student engagement, concept visualization, and multiple problem-solving strategies. Involving MGMP as a professional community helped ensure that the training was grounded in real teaching contexts, allowing teachers to collaborate, share insights, and co-develop instructional resources relevant to their students. These findings underscore the importance of professional development programs that are collaborative, practical, and closely tied to everyday classroom realities.

Recommendations

Based on the findings of this study, several recommendations can be offered to improve future training initiatives involving technology integration in mathematics education. First, it is important to consider extending the duration of training to allow participants more time for hands-on practice and deeper exploration of the software's features. A follow-up program, either online or in-person, could support continued development and address challenges that arise during classroom implementation. It is also recommended that teachers be given opportunities to test their GeoGebra-based instructional products directly in the classroom, so they can evaluate their effectiveness with students and refine their design. In addition, creating a network or forum for participating teachers would foster ongoing collaboration, idea exchange, and peer support. Finally, closer partnerships between universities and teacher communities such as MGMP should be strengthened to ensure that training programs remain contextually relevant, sustainable, and responsive to the actual needs of educators in the field.

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