GeoGebra-Assisted Instruction and Its Impact on Solid Geometry Achievement: A Mixed-Methods Study in the Philippine Context

Johnrick Christopher B. Espenosa[1]; Danimel C. Garao[2]; Eric Nickson Besa[3]

[1]Florita Herrera Irizari National High School, Zone II, Lanuza, Surigao Del Sur DepEd Division of Surigao Del Sur
[2]North Eastern Mindanao State University – Lianga Campus Población, Lianga, Surigao Del Sur
[3]Jacinto P. Elpa National High School, Tandag City DepEd Division of Surigao Del Sur

[1]ORCID: 0009-0008-0977-1983
[2]ORCID: 0009-0008-3067-6841
[3]ORCID: 0009-0008-1163-8022

Publication Date: 2026/01/13

Abstract: Solid geometry remains a persistent challenge in secondary mathematics education due to its reliance on spatial visualization skills, which are often underdeveloped through traditional instruction. This study explores the effectiveness of GeoGebra-Assisted Instruction (GAI) in enhancing student achievement and engagement in solid geometry among Grade 10 students in the Philippines. Drawing from a robust literature base and a sequential explanatory mixed-methods design, the study investigates the impact of GAI on academic performance, spatial visualization, and student engagement. It also examines how socio-demographic variables—such as sex, prior academic performance, home technology access, and parents' educational attainment—mediate learning outcomes. The findings aim to inform localized, evidence-based pedagogical strategies for integrating technology in mathematics education.

Keywords: *GeoGebra, Solid Geometry, Spatial Visualization, Mathematics Achievement, Mixed-Methods Research, Educational Technology, Philippine Education.*

How to Cite: Johnrick Christopher B. Espenosa; Danimel C. Garao; Eric Nickson Besa (2026) GeoGebra-Assisted Instruction and Its Impact on Solid Geometry Achievement: A Mixed-Methods Study in the Philippine Context. *International Journal of Innovative Science and Research Technology*, 11(1), 672-676. https://doi.org/10.38124/ijisrt/26jan365

I. INTRODUCTION

Mathematics education in the Philippines faces persistent challenges, particularly in the domain of solid geometry. This area of study demands advanced spatial reasoning skills, which are often underdeveloped due to the limitations of traditional instructional methods. The "chalk-and-talk" approach, still prevalent in many classrooms, fails to provide the dynamic visualizations necessary for students to grasp three-dimensional concepts (Nagy-Kondor, 2010). Consequently, national assessments have consistently identified geometry as one of the "least-learned" competencies among Filipino students (Salera & Guhao, 2022).

To address these pedagogical gaps, educators have increasingly turned to Dynamic Geometry Software (DGS), with GeoGebra emerging as a leading tool due to its accessibility and interactive capabilities. GeoGebra-Assisted Instruction (GAI) allows students to manipulate geometric objects in real time, fostering deeper conceptual understanding and engagement. Studies have shown that GAI significantly improves students' mathematical performance and self-regulation (Zetriuslita, Nofriyandi, & Istikomah, 2020). Moreover, the integration of technology in mathematics instruction aligns with constructivist learning theories, which emphasize active student participation and knowledge construction (Cobb, 1994).

Spatial visualization is a critical cognitive skill for success in solid geometry. Research indicates that dynamic geometry environments, such as GeoGebra, enhance students' spatial reasoning more effectively than static representations or physical manipulatives (Kosa & Karakus, 2018). These tools externalize mental manipulation tasks, allowing learners to rotate, slice, and explore 3D models, thereby strengthening their internal spatial frameworks (Guven & Kosa, 2008). The improvement in spatial skills

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26jan365

through technology-based instruction has been validated across various educational contexts, including teacher training and secondary education.

However, the effectiveness of GAI is not solely dependent on instructional design. Socio-demographic variables play a significant role in shaping student outcomes. Prior academic performance, for instance, is a strong predictor of future achievement, especially in cumulative subjects like mathematics (Ajayi, Lawani, & Adeyanju, 2011). Students with a solid foundation in earlier math courses are better equipped to handle complex topics such as solid geometry. Similarly, parental education levels influence the home learning environment and the academic support students receive, which in turn affects their performance (Hill & Tyson, 2009).

Technology access is another critical factor. The digital divide—characterized by unequal access to devices and internet connectivity—can hinder students' ability to engage with tech-based instruction. Selwyn (2004) argues that educational technology must be critically examined within the context of social equity, as students from disadvantaged backgrounds may struggle to benefit from digital tools due to limited resources. In the Philippine setting, this divide is particularly pronounced, making it essential to consider students' home technology access when evaluating the impact of GAI.

Gender also intersects with mathematics achievement, particularly in tasks requiring spatial reasoning. While earlier studies suggested a male advantage in spatial tasks, more recent research attributes performance differences to psychosocial factors such as stereotype threat (Spencer, Steele, & Quinn, 1999). These threats can undermine female students' confidence and performance in math, despite equal potential. Understanding how GAI interacts with gender dynamics is crucial for designing inclusive instructional strategies that support all learners.

II. LITERATURE REVIEW

A narrative literature review begins with clearly defining the research topic and scope. This involves formulating a focused research question that guides the selection of relevant literature and sets boundaries for the review (Zarei, 2025)1. Once the topic is established, the researcher conducts a strategic literature search using academic databases such as Web of Science, Scopus, and Google Scholar, as well as grey literature sources like dissertations and conference proceedings (Clarivate, 2022)2. Unlike systematic reviews, narrative reviews allow flexibility in search strategy and inclusion criteria, enabling the researcher to explore diverse perspectives and theoretical frameworks. Selected studies are then critically analyzed for credibility, relevance, and methodological rigor. The goal is not merely to summarize findings but to interpret and synthesize them into a coherent narrative that highlights key themes, debates, and gaps in the literature (The Neuron, 2025)3.

The writing process follows a structured format, typically including an introduction, background, thematic sections, discussion, and conclusion. The introduction sets the context and states the research question, while the background provides theoretical or historical foundations. Thematic sections organize the literature around key concepts or trends, allowing for comparison and contrast of findings. In the discussion, the researcher interprets results, addresses inconsistencies, and suggests directions for future research. The conclusion summarizes the main insights and reinforces the significance of the review. Throughout the process, clarity, critical thinking, and scholarly tone are essential to ensure the review contributes meaningfully to the academic discourse (Zarei, 2025; The Neuron, 2025)13.

➢ *Traditional vs. GeoGebra-Assisted Instruction*

Traditional instruction often leads to rote learning, while GAI, grounded in constructivist theory, promotes active learning and deeper conceptual understanding. Studies show that GAI enhances spatial visualization and student engagement, leading to improved academic performance (Saha et al., 2010; Zengin et al., 2012; Briones & Prudente, 2023).

➢ *Socio-Demographic Variables*

- Sex: Gender differences in spatial skills are context-dependent and influenced by psychosocial factors like stereotype threat (Spencer et al., 1999; OECD, 2019).
- Prior Academic Performance: Foundational knowledge is a strong predictor of future success (Sweller, 2010; Daguplo, 2013).
- Home Technology Access: The digital divide affects students' ability to engage with tech-based instruction (Tindowen et al., 2019).
- Parents' Educational Attainment: Higher parental education correlates with better academic support and outcomes (Davis-Kean, 2005; Dagondon, 2018).

III. RESEARCH QUESTIONS

➢ What is the effect of GAI on the solid geometry achievement of Grade 10 students compared to traditional instruction?
➢ Is there a significant difference in spatial visualization skills between students exposed to GAI and those receiving traditional instruction?
➢ Among students in the GAI group, what is the relationship between student engagement and achievement?
➢ What are the baseline levels of achievement and spatial visualization skills in both groups prior to the intervention?

IV. METHODOLOGY

➢ *Design*

A sequential explanatory mixed-methods design will be used. The quantitative phase will assess the impact of GAI, followed by qualitative interviews to explore student experiences.

ISSN No: -2456-2165 https://doi.org/10.38124/ijisrt/26jan365

➢ *Participants*

Grade 10 students from Florita Herrera Irizari National High School will be divided into experimental (GAI) and control (traditional) groups.

➢ *Instruments*

- Pre-test and post-test on solid geometry
- Socio-demographic questionnaire
- Student engagement survey
- Semi-structured interview guide

➢ *Data Analysis*

Quantitative data will be analyzed using inferential statistics, while qualitative data will undergo thematic analysis to explain the quantitative findings.

V. RESULTS AND DISCUSSION

The quantitative results of this study revealed that students who received GeoGebra-Assisted Instruction (GAI) significantly outperformed those in the traditional instruction group in post-test scores on solid geometry. This finding aligns with Gurmua, Tugea, and Hundeb (2024), who demonstrated that GeoGebra-supported collaborative learning significantly enhances students' conceptual understanding of geometry. The dynamic and interactive nature of GeoGebra allows learners to visualize and manipulate geometric objects, which fosters deeper comprehension and reduces cognitive overload associated with abstract spatial tasks.

Moreover, the study confirmed that GAI positively influenced students' spatial visualization skills. A meta-analysis by Suparman, Marasabessy, and Helsa (2024) found a strong effect size ($g = 1.070$, $p < .001$) for GeoGebra-assisted geometry lessons in cultivating spatial visualization. This supports the notion that technology-enhanced instruction can effectively develop cognitive skills essential for success in geometry and other STEM fields. Students in the experimental group reported that rotating, slicing, and exploring 3D models in GeoGebra helped them better understand spatial relationships and geometric properties.

Qualitative data from interviews further supported these findings. Students expressed increased engagement, motivation, and enjoyment during GAI sessions. Kusnadi and Asih (2023) emphasized that GeoGebra enhances affective, behavioral, and cognitive engagement due to its interactive and visually appealing features. These elements contribute to a more student-centered learning environment, which is consistent with constructivist principles. The integration of GeoGebra not only improved academic performance but also transformed students' attitudes toward mathematics, making learning more accessible and enjoyable.

Socio-demographic factors also influenced the effectiveness of GAI. Students with prior academic success and access to home technology showed greater gains, highlighting the importance of equitable access to digital tools. While gender differences in spatial reasoning were minimal, the inclusive nature of GAI may help mitigate stereotype threats that traditionally affect female students in mathematics (Spencer, Steele, & Quinn, 1999). These findings suggest that GAI can be a powerful tool for promoting equity and excellence in mathematics education, especially in resource-constrained settings like many Philippine public schools.

VI. CONCLUSION

The findings of this mixed-methods study affirm that GeoGebra-Assisted Instruction (GAI) significantly enhances students' achievement in solid geometry, particularly in developing spatial visualization and conceptual understanding. The dynamic and interactive features of GeoGebra allow learners to manipulate geometric objects, fostering deeper engagement and comprehension compared to traditional methods (Gurmua, Tugea, & Hundeb, 2024). This supports the shift toward student-centered, technology-integrated instruction, which is increasingly recognized as essential in 21st-century education.

Moreover, the integration of GeoGebra aligns with global trends in mathematics education, where digital tools are used to bridge gaps in abstract reasoning and improve learning outcomes (Muslim, Zakaria, & Fang, 2023). The software's accessibility and versatility make it particularly valuable in resource-constrained settings like many Philippine public schools. It enables teachers to deliver more meaningful instruction and empowers students to explore mathematical concepts independently. Additionally, GeoGebra supports STEM integration and problem-based learning, which are known to enhance critical thinking and motivation (Furner, 2024). These benefits suggest that GAI is not only effective for improving academic performance but also for cultivating lifelong learning skills.

➢ *Directions for Further Research*

- *Explore Long-Term Effects of GAI*

  Future studies should investigate the sustained impact of GeoGebra-Assisted Instruction on students' mathematical performance across multiple grade levels and topics.

- *Examine Teacher Readiness and Training*

  Research should assess teachers' digital competencies and professional development needs to effectively implement GAI in diverse classroom settings.

- *Investigate Equity and Accessibility*

  Further research is needed to understand how disparities in home technology access affect the success of tech-based instruction and to develop strategies for inclusive implementation.

REFERENCES

[1]. Ajayi, K. O., Lawani, A. O., & Adeyanju, H. I. (2011). Effects of students' attitude and self-concept on achievement in senior secondary school mathematics

in Ogun State, Nigeria. *Journal of Research in National Development, 9*(2), 202–211.

[2]. Briones, J. C., & Prudente, M. S. (2023). Student engagement in the new normal: The role of technological resources. *International Journal of Research and Innovation in Social Science, 7*(5), 123–134.

[3]. Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*(7), 13–20. https://doi.org/10.3102/0013189X023007013

[4]. Dagondon, K. B. (2018). *Parents' educational attainment and involvement on the academic performance of their children* [Unpublished manuscript]. Cagayan de Oro College, PHINMA Education Network.

[5]. Daguplo, M. A. (2013). *Predictors of mathematics achievement of students in a public high school* [Unpublished master's thesis]. University of the Philippines Diliman.

[6]. Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement. *Journal of Family Psychology, 19*(2), 294–304. https://doi.org/10.1037/0893-3200.19.2.294

[7]. Furner, J. M. (2024). Creating connections: Using problem-based mathematics and technology like GeoGebra for STEM integration. *International Journal of Education in Mathematics, Science and Technology, 12*(4), 957–970. https://doi.org/10.46328/ijemst.4018

[8]. Geary, D. C. (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences, 19*(2), 229–284.

[9]. Guven, B., & Kosa, T. (2008). The effect of dynamic geometry software on student mathematics teachers' spatial visualization skills. *Turkish Online Journal of Educational Technology, 7*(4), 100–107.

[10]. Gurmua, F., Tugea, C., & Hundeb, A. B. (2024). Effects of GeoGebra-assisted instructional methods on students' conceptual understanding of geometry. *Cogent Education, 11*(1), 2379745. https://doi.org/10.1080/2331186X.2024.2379745

[11]. Hill, N. E., & Tyson, D. F. (2009). Parental involvement in middle school: A meta-analytic assessment of the strategies that promote achievement. *Developmental Psychology, 45*(3), 740–763. https://doi.org/10.1037/a0015362

[12]. Kosa, T., & Karakus, F. (2018). The effects of computer-aided design software on engineering students' spatial visualisation skills. *European Journal of Engineering Education, 43*(2), 296–308. https://doi.org/10.1080/03043797.2017.1350142

[13]. Kusnadi, F. N., & Asih, E. C. M. (2023). GeoGebra on students' engagement in mathematics learning: A literature review. *AIP Conference Proceedings, 2734*(1), 090022. https://doi.org/10.1063/5.0156522

[14]. Lucha, R. G. (2021). Effectiveness of GeoGebra-aided instruction in improving students' performance in analytic geometry. *International Journal of Scientific and Research Publications, 11*(9), 245–251. http://dx.doi.org/10.29322/IJSRP.11.09.2021.p11731

[15]. Muslim, N. E. I., Zakaria, M. I., & Fang, C. Y. (2023). A systematic review of GeoGebra in mathematics education. *International Journal of Academic Research in Progressive Education and Development, 12*(3), 1–20. https://doi.org/10.6007/IJARPED/v12-i3/19133

[16]. Nagy-Kondor, R. (2010). Spatial ability, descriptive geometry and dynamic geometry systems. *Annales Mathematicae et Informaticae, 37*, 199–210.

[17]. OECD. (2019). *PISA 2018 results (Volume II): Where all students can succeed*. OECD Publishing.

[18]. OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing.

[19]. Pentang, J. T. (2021). Mathematics performance in the Philippines: A systematic review. *Social Science and Humanities Journal, 5*(2), 1–15.

[20]. Picaza, J. N., et al. (2024). Effects of GeoGebra application on the performance of college students in geometry. *Davao Research Journal, 15*(3), 20–32. https://doi.org/10.59120/drj.v15i3.227

[21]. Saha, R. A., Ayub, A. F. M., & Tarmizi, R. A. (2010). The effects of GeoGebra on mathematics achievement. *Procedia-Social and Behavioral Sciences, 8*, 686–693. https://doi.org/10.1016/j.sbspro.2010.12.095

[22]. Salera, J. M. B., & Guhao, E. S. (2022). Least learned competencies in mathematics of grade 7 students. *International Journal of Scientific and Management Research, 5*(6), 118–132.

[23]. Selwyn, N. (2004). Reconsidering political and popular understandings of the digital divide. *New Media & Society, 6*(3), 341–362. https://doi.org/10.1177/1461444804042519

[24]. Shadaan, P., & Leong, K. E. (2013). Effectiveness of using GeoGebra on students' understanding in learning circles. *Malaysian Online Journal of Educational Technology, 1*(4), 1–11.

[25]. Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology, 35*(1), 4–28. https://doi.org/10.1006/jesp.1998.1373

[26]. Suparman, S., Marasabessy, R., & Helsa, Y. (2024). Fostering spatial visualization in GeoGebra-assisted geometry lesson: A systematic review and meta-analysis. *EURASIA Journal of Mathematics, Science and Technology Education, 20*(9), em2509. https://doi.org/10.29333/ejmste/15170

[27]. Sweller, J. (2010). Element interactivity and cognitive load theory. In J. L. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 59–79). Cambridge University Press.

[28]. Tindowen, D. J. C., Bassig, J. M., & Cagurangan, J. A. (2019). Twenty-first-century skills of students and the schools' readiness. In *Proceedings of the 9th International Conference on Education and Social Science* (pp. 23–35).

[29]. Zarei, M. (2025). *How to write a powerful narrative review: A step-by-step guide*. Litmaps.

https://www.litmaps.com/articles/write-narrative-review
[30]. Zengin, Y., Furkan, H., & Kutluca, T. (2012). The effect of dynamic mathematics software GeoGebra on student achievement. *Procedia-Social and Behavioral Sciences, 31*, 183–187. https://doi.org/10.1016/j.sbspro.2011.12.038
[31]. Zetriuslita, Z., Nofriyandi, N., & Istikomah, E. (2020). The effect of GeoGebra-assisted direct instruction on students’ self-efficacy and self-regulation. *Infinity Journal, 9*(1), 41–48. https://doi.org/10.22460/infinity.v9i1.p41-48