INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS

ISSN(print): 2643-9840, ISSN(online): 2643-9875

Volume 08 Issue 07 July 2025

DOI: 10.47191/ijmra/v8-i07-56, Impact Factor: 8.266

Page No. 4210-4219

Teaching Approaches and Students' Conceptual Understanding in Geometry

Christeus Von S. Sujero[1], Rebecca A. Alcuizar[2]

[1]Southern de Oro College, Cagayan de Oro City, Philippines

[2]Mindanao State University Iligan Institute of Technology, Iligan City, Philippines

ABSTRACT: This study explores the relationship between Geometry teachers' teaching approaches and students' conceptual understanding in Geometry. It sought to determine the level of teaching approaches in terms of Guided Practice, Lecture-Based, and Collaborative Learning and how these relate to students' level of conceptual understanding. Employing a descriptive-correlational research design, the study was conducted among Grade 8 students from three private schools in Cagayan de Oro City. Stratified random sampling was used to select student respondents from Capitol University Basic Education Department, Pilgrim Christian College, and Southern de Oro Philippine College. The instruments used were a self-made survey checklist to identify observed teaching approaches and a researcher-made test to assess students' conceptual understanding. Data were analyzed using mean, standard deviation, and Pearson Product Moment Correlation Coefficient. Results revealed that Collaborative Learning was the most dominant teaching approach, while students demonstrated a less satisfactory level of conceptual understanding; significant positive relationships were also found between Guided Practice and Lecture-Based instruction with students' understanding. It was concluded that teaching strategies notably influence how well students grasp geometric concepts. It is recommended that teachers enhance the use of guided and lecture-based strategies while enriching collaborative learning practices to improve student outcomes in Geometry.

KEYWORDS: collaborative learning, conceptual understanding, guided practice, lecture-based instruction

I. INTRODUCTION

Mathematics education serves as the core foundation for enhancing mathematical problem solving, modelling, and creative thinking. Among the vast branches of mathematics, geometry presents a special dimension because of its use in many fields, such as engineering, architecture, and the natural sciences. However, learning a concept in this geometry area has become difficult for learners. Geometry is both abstract and cognitive, meaning a student must relate theoretical concepts with application. Thus, suggestions toward viable methods and strategies that may provide some solution to this need to pursue further checks in enhancing students through effective methodologies. Using the purpose of this research, three distinct teaching methods believed to help surface the conceptual understanding of selected geometry topics include guided practice, lecture-based instruction, and collaborative learning.

Conceptual understanding is central to mathematical proficiency, which means a deep understanding of the logic involved, the relationship-forming regularity, and the application of concepts learned in new areas. Thompson (2020) argues that constructivist approaches in mathematics education are directed at leveraging students' prior knowledge, which forms the foundation for a deep understanding. Still, many classrooms remain driven by traditional lecture-based approaches that may not suit all students' varied needs. Lee (2021) picks on one of these barriers: while active learning strategies do not favor anything compared to traditional methods, they regularly yield better student engagement and performance. Guided practices combine direct instruction and active participation and have shown promise in supporting students in understanding complex conceptual material by providing the necessary scaffolding and feedback. Collaborative learning immersed in peer interaction, as explored by Schwarz et al. (2021), enhances learning through collective problem-solving and modelling peer knowledge construction and concept construction in a very collaborative environment.

Since this research focused on the selected topic competencies, it found the most effective teaching approach to enhancing conceptual understanding in geometry. After the students completed the survey checklist, which highlighted the dominant teaching approach they perceived in their classrooms, student responses were recorded with the conceptual understanding test outcomes on five geometry topics. The integrations of the student's conceptual understanding seek to evaluate the effectiveness of the guided-practice, lecture-based instruction, and collaborative learning teaching approach. Charles (2020) suggests that inquiry-based and guided practice strategies significantly enhance students' conceptual understanding and achievement. However, very few comparative studies have been done to specifically examine the impact of guided practice, lecture-based instruction, and collaborative learning. This study thus contributes to the growing body of evidence in support of evidence-based practices of teaching mathematics. Moreover, Schwarz et al. (2021) suggest that teachers must monitor and track the progress of students' progress in collaborative learning classroom to work toward more fair, accessible, and effective outcomes.

The evidence from this study has overwhelmingly far-reaching implications, as its findings concern both classroom application and educational policy reform. Determining the teaching strategy that best contributes to conceptual understanding in geometry should guide teachers in designing their pedagogies to meet the students' differing needs. In addition, Lee (2021) claims that classroom-guided practice can transform mathematics education by supporting student-centered learning and fostering increased engagement in the studied content.

This study carried an inquiry into the effectiveness of guided practice, lecture-based instruction, and collaborative learning techniques toward discovering what works best at developing students' conceptual understanding across the content areas in geometry. Integration of the teaching strategies applied by students and the success they achieved thereby offers a holistic outlook on instructional efficacy.

This study's theoretical foundations relied on established educational theories on how students should be taught, acquire, process, and apply conceptual knowledge, especially in mathematics, focusing on geometry. Three broad theoretical frameworks guide this study: Cognitive Learning Theory, Activity Theory, and Constructivist Learning Theory. All three theories

These theories provide a unified lens through which the effectiveness of guided practice compared to lecture-based instruction or collaborative learning in enhancing students' conceptual understanding of geometry can be assessed.

Cognitive Learning Theory emphasizes the processes involved in skill acquisition, information processing, and the development of conditional knowledge. Aprilia (2024) and Oco (2024) states that learning occurs through the active engagement of cognitive structures, where students organize and integrate new information into pre-existing mental frameworks. The theory supports guided practice, which combines teacher-centered instruction with student participation to scaffold learning. By giving areas of discipline to practice drills and exercises, guided practice enables students to strengthen their conceptual understanding and transfer knowledge across contexts. The computational nature of this approach connects to cognitive processing, ensuring that students not only acquire procedural fluency but also develop more profound insights into the relationships among geometric concepts.

Activity Theory offers a sociocultural lens whereby its tools, activities, and social interactions provide a provision for understanding learning experiences. Nikou (2023) notes how motivation and engagement engender effective learning in developed activities. Meaningful learning arises from the midst of interactions among self-goals and collaborative processes. The framework gives a basis for studying collaborative learning as a formative approach. Through working on problem-based tasks oriented toward groups, collaborative learning promotes interpersonal interaction among learners, shared knowledge building, and their ability to transfer geometric concepts into real-life contexts. Activity Theory emphasizes the essence of context, collaboration, and tools in developing a conceptual understanding among students, hence in line with the focus of the study on multi-faceted pedagogies.

Constructivist Learning Theory proposes that learners construct knowledge through interactions with peers, teachers, and the environment. Angraini et al. (2024) imply that constructivist learning theory allows the students to experience computational thinking and reasoning. This theory corresponds to collaborative learning and guided practice, highlighting interactive participation and metacognition of meaning. Constructivist principles posited in the context of lecture-style instruction additionally assert that for meaningful learning to take place potentially, teaching must bridge theoretical responses with students' prior knowledge in creating a learning experience. Constructivist strategies give students a well-rounded grasp of geometric concepts since they locate students' learning experiences within authentic and pertinent contexts.

These theoretical perspectives thus come together to offer a comprehensive landscape of how methods of instruction affect students' notions of understanding in geometry. Cognitive Learning Theory focuses on internal processes, internal learning mechanisms, skill acquisition, and knowledge transfer. It is extended by Activity Theory, which situates learning as being collaborative in contextualized settings -ACT supports the learning process through social interactions. Constructivist Learning Theory bridges the two perspectives by advancing an agenda of active engagement and profitable learning. By combining these theories, this study seeks to explore how guided practice, lecture-based instruction, and collaborative learning influence complementarily converging towards students' conceptual development through selected topics in geometry.

Teaching Approaches and Students' Conceptual Understanding in Geometry

The study overview provides the base for probing how different teaching styles interact with students' progression in the context of geometry—drawing on these three theories in terms of their literature. The Cognitive Learning Theory, Activity Theory, and Constructivist Learning Theory are the interests of the greater debate about evidence-based instructional practices in mathematics education; the study hopes to support educators when running targeted educational strategies.

II. METHODOLOGY

The study, Teaching Approaches and Conceptual Understanding in Geometry, employed a descriptive correlational research design to examine the relationship between various teaching approaches and students' conceptual understanding in geometry. This design was appropriate as it allows the researcher to describe the existing teaching methods, such as guided practice, lecture-based instruction, and collaborative learning, while simultaneously determining whether these approaches are significantly related to students' academic performance in geometry.

This study adopted a descriptive approach to illustrate how each teaching method is applied in real classroom settings. At the same time, a correlational analysis was used to explore potential links between instructional strategies and students' performance on a geometry test. It's important to recognize that while correlations can point to potential connections between variables, they should not be interpreted as evidence of direct causation.

III. RESULTS AND DISCUSSION

Problem 1. What is the level of Geometry teachers' teaching approach in terms of:

1.1 guided practice;

1.2 lecture – based instruction;

1.3 collaborative learning?

Table 1: Summary Table for Teaching Approaches

Variables	Mean	SD	Description	Interpretation
Guided Practice	3.38	0.64	Strongly Agree	Highly Observed
Lecture-based Instruction	3.33	0.67	Strongly Agree	Highly Observed
Collaborative Learning	3.45	0.63	Strongly Agree	Highly Observed
Overall Mean	**3.39**	**0.65**	**Strongly Agree**	**Highly Observed**

Note: 3.26-4.00 - Highly Observed 2.51-3.25 – Observed 1.76-2.50 - Less Observed 1.00-1.75 - Least Observed Highly Observed.

Table 1 displays the overall summary for teaching approaches. It has an overall Mean of 3.39 with SD = 0.65, described as Strongly Agree and interpreted. This means that the teacher implements differentiated instruction in a classroom setting. This implies that the Geometry teachers employed varied teaching approaches that will catch the attention and interest of their students. This finding also suggests that the students consistently recognized and engaged with these teaching approaches, reinforcing their effectiveness in facilitating learning. The relatively similar mean values across the three approaches: guided practice (M = 3.38), lecture-based instruction (M = 3.33), and collaborative learning (M = 3.45), imply that each method holds significant value in shaping students' conceptual understanding. The standard deviations of 0.63-0.67 reveal that the students had relatively uniform awareness of the strategies used in the instruction. Such findings are corroborated by Deslauriers et al. (2019), which emphasizes the importance of active participation in learning environments and shows how different approaches of instruction used work towards augmenting meaningful learning experiences.

Of the three instructional strategies that were under study, collaborative learning scored the highest with the mean of 3.45 with SD = 0.63 described as Strongly Agree and interpreted as Highly Observed. This indicates that students rated this approach very highly as exceptionally useful and interesting. The collaborative learning has impacted the students to engage actively in groups and share their ideas among their peers. It becomes a student-friendly approach to the high school learners in teaching-learning process. This is also a pointer to the significance of interactive learning settings in facilitating deeper learning and active engagement. Collaborative learning encourages student-centered learning, teamwork, and critical thinking, which allow learners to co-construct knowledge rather than receive information passively (Hwang et al., 2022). The validity of such an approach is also ensured by Palisbo et al. (2025), who authenticated that the implementation of collaborative strategies in teaching geometry has a powerful impact on learners' motivation as well as their problem-solving potential.

Additionally, Ruipérez-Valiente and Kim (2020) emphasized that students who engage in collaborative problem-solving tend to demonstrate higher retention rates and better conceptual understanding compared to those learning in isolation. These findings suggest that when students work together, they are more likely to develop a deeper grasp of mathematical concepts, as they actively communicate from their peers.

On the other hand, lecture-based instruction received the lowest score with a mean score of 3.33 with SD = 0.67 described as Strongly Agree and Highly Observed. Due to its convenient teaching style, the teacher can conceptualize properly the topic through open discussion and verbal exchange of ideas. Although conventional lectures are still a significant component of instruction delivery, their marginal drop in perceived effectiveness could imply that students may perceive this method as less interactive than participatory instruction. Traditional lecture-based teaching, when not supplemented with interactive strategies, often leads to passive learning, where students may struggle to retain information effectively (Active Learning Strategies, 2024). However, empirical evidence suggests that lecture-based instruction techniques can work if they are integrated with active learning strategies such as instructor follow-up, questioning, and application (Machaba & Mangwiro, 2024). The integration of these factors by instructors in lectures increases the chances of learner engagement and builds a better grasp of the topic.

The study highlights that despite the effectiveness of all three learning approaches, the most highly respected approach was found to be collaborative learning. Such a result agrees with the recent body of work indicating student-oriented teaching methodologies stressing engagement, interaction, and deeper learning experiences (Oco, 2022; Uygun, 2020; Gillies, 2019). While lecture-centered instruction still prevails in structured content delivery, the implementation of collaborative and guided practice models proves to be a more powerful process in the realization of deeper learning experiences, as in mathematics, in this research. The result indicates that these teaching methods, in combination as interdependent practice, must address multiple learning preferences and optimize student conceptual understanding. In the coming years, educators must consider the cultivation of more collaborative learning environments alongside selective use of lectures and guided practice to enhance complete student growth.

Problem 2. What is the level of students' conceptual understanding in Geometry?

Table 2: Conceptual Understanding in Geometry

Competencies	Mean	SD	Interpretation
1. Describes a mathematical system	3.08	1.82	Understood
2. Illustrates the need for an axiomatic structure of mathematical concepts, in general.	2.61	1.71	Less Understood
3. Illustrates triangle congruence	3.26	1.80	Understood
4. Illustrates SAS, ASA, and SSS congruence postulate	2.41	1.68	Less Understood
5. Solves corresponding parts of congruent triangles	2.18	1.56	Less Understood
Overall Mean	**2.71**	**1.76**	**Less Understood**

Note: .4.6 – 6.0 - Well Understood 3.1 – 4.5 – Understood 1.6 – 3.0 - Less Understood 0 – 1.5 - Least Understood

Table 2 reveals the Level of Conceptual Understanding in Geometry. It has an overall mean of 2.71 with SD = 1.76 interpreted as Less Understood. This implies that while some learners may grasp specific topics, there remains a significant gap in fully internalizing essential geometric concepts. In other words, the students are having some difficulty in absorbing conceptual knowledge and geometric facts upon learning. As Hershkowitz (2020) emphasized, geometry is a foundation for building spatial reasoning and logical structures, but when students lack robust engagement and scaffolded instruction, comprehension may become fragmented and stagnant. Similarly, Donlan (2021) highlights that a learner's ability to link procedural skills with conceptual frameworks is often hindered without meaningful application and consistent feedback. These findings suggest the need for more learner-centered strategies that support long-term conceptual development.

Furthermore, the competency, *Illustrate triangle congruence*, received the highest mean rank. It has an overall mean of 3.26 with SD = 1.80 interpreted as Understood. This reflects students' stronger grasp of visual and procedural tasks that involve identifying congruent shapes—possibly due to frequent use of diagrams and visual models in instruction. This also indicates that learning has been maximized because this competency requires figures and visual representation which makes the concepts easy to understand. Dugay and Pasia (2023) affirm that open-ended and visual tasks in geometry tend to foster better retention and engagement among learners. Additionally, Patac et al. (2022) noted that when students are provided opportunities to pose and solve geometric problems related to congruence, their conceptual clarity improves. The researcher interprets this outcome as a sign that students benefit from tangible, relatable topics—especially those linked with real-world symmetry and shape comparisons.

Additionally, the competency 5, *Solves corresponding parts of congruent triangles*, received the lowest mean rank. It has an overall mean of 2.18 with SD = 1.56 interpreted as Less Understood. This means that the learners are showing some intricacy in problem-solving and higher order thinking skills. This indicates that students struggle with applying theoretical knowledge to solve problems requiring multi-step reasoning or abstract connection of properties. According to Luzano (2023), a weak foundation in problem-solving competencies and conceptual connections can inhibit students' ability to move from recognition to deduction in geometry. Kania and Juandi (2023) further argue that low self-concept and insufficient scaffolding may result in students disengaging from cognitively demanding tasks. Thus, the researcher recognizes a critical need for interventions that reinforce these complex applications through guided practice, collaborative discussion, and repeated exposure to congruence-based proofs in meaningful contexts.

Problem 3. Is there a significant relationship between the level of Geometry teachers' teaching approaches and students' conceptual understanding in Geometry?

Table 3 presents a correlation analysis between different teaching approaches—Guided Practice, Lecture-Based, and Collaborative Learning—and students' overall Conceptual Understanding Score in mathematics. All three instructional methods demonstrated statistically significant relationships, with p-values of 0.000. Among them, Collaborative Learning (r = 0.346) and Guided Practice (r = 0.322) revealed moderate positive correlations, whereas Lecture-Based teaching (r = 0.276) yielded a low positive correlation. The consistent rejection of the null hypothesis across all variables suggests that each teaching method has a significant relationship with conceptual understanding, albeit to varying degrees of strength. These findings highlight that while all approaches contribute, certain strategies may be more effective in enhancing conceptual depth among learners.

Collaborative Learning emerged as the teaching approach with the strongest correlation to students' conceptual understanding. The moderate positive relationship suggests that peer-based and interactive environments are conducive to deeper learning. This supports the findings of Mutaqin et al. (2021), who asserted that collaborative strategies grounded in Realistic Mathematics Education (RME) help bridge abstract concepts with real-world contexts, thereby enriching students' conceptual grasp. Likewise, Jablonski and Ludwig (2023) emphasized the current shift toward learner-centered geometry instruction, where collaborative learning promotes discourse, reasoning, and flexible thinking—key elements of conceptual understanding. The significant association found here reinforces the pedagogical value of involving students actively in knowledge construction through interaction and shared problem-solving.

Table 3: Summary of Correlation of Teaching Approaches and Overall Conceptual Understanding Score

Independent Variables	r-value	p-value	Description	Decision on Ho	Interpretation
Guided Practice	0.322**	0.000	Moderate Positive	Reject	Significant
Lecture-based	0.276	0.000	Low Positive	Reject	Significant
Collaborative Learning	0.346**	0.000	Moderate Positive	Reject	Significant

**. Correlation is significant at the 0.01 level (2-tailed).

Guided Practice followed closely with a moderately positive correlation to conceptual understanding, suggesting that scaffolded instruction is also an effective strategy. This approach allows for structured learning pathways where students are gradually supported toward independent conceptual mastery. According to Wu and Wang (2022), instructional approaches that combine teacher guidance with student engagement often yield strong results in mathematics performance, particularly in geometry and algebra. Furthermore, Mutawah et al. (2019) identified that blending procedural practice with conceptual framing enhances learners' ability to transfer knowledge to new problems—indicating that guided instruction, when properly implemented, strengthens conceptual foundations while reinforcing skills.

Although statistically significant, Lecture-Based instruction had the weakest correlation among the three methods, marked as a low positive relationship. This suggests that while traditional teaching methods can still contribute to conceptual understanding, they may not be as impactful as more interactive approaches. Lumbre et al. (2023) pointed out that teachers' Van Hiele levels—a framework for understanding geometric thought—play a crucial role in shaping how effectively they can convey conceptual material through lectures. Additionally, Sunzuma and Maharaj (2020) found that reliance on one-way transmission of knowledge often limits opportunities for conceptual engagement, particularly in culturally diverse settings. Therefore, while lectures remain a staple in mathematics education, their influence on conceptual depth may be limited without complementary, student-centered strategies.

IV. CONCLUSIONS

Based on the findings, the following conclusions are drawn:

1. The geometry teachers practiced differentiated instruction in a classroom setting since all of the teaching approaches were highly observed.
2. The students' retention to geometric concepts is low which leads to poor conceptual understanding.
3. Geometry teachers find collaborative learning effective and interactive in improving students' conceptual understanding.

V. RECOMMENDATIONS

Based on the findings and conclusions, the following recommendations are formulated:

1. Geometry teachers should continue to apply the aforementioned teaching approaches in teaching and integrate new trends in education and pedagogy in the teaching-learning process.
2. The school should implement after-school tutorials, differentiated instruction, and diagnostic assessment to address the learning gap in geometry.
3. Teachers should enhance the use of guided and lecture-based strategies while enriching collaborative learning practices to improve student outcomes in Geometry and explore different teaching approaches for further studies.

REFERENCES

1) Abuhasanein Youssef, Abdessatar Rejeb, & Khaled Jemai. (2025). Challenges to learning mathematical concepts among sixth-grade students in primary education: A teachers' perspective. International Electronic Journal of Mathematics Education, 20(2), em0818–em0818. https://doi.org/10.29333/iejme/15918
2) Abdulrahaman, M. D., Faruk, N., Oloyede, A. A., Surajudeen-Bakinde, N. T., Olawoyin, L. A., Mejabi, O. V., Imam-Fulani, Y. O., Fahm, A. O., & Azeez, A. L. (2020). Multimedia tools in the teaching and learning processes: A systematic review. Heliyon, 6(11), 1–14. https://doi.org/10.1016/j.heliyon.2020.e05312
3) Active Learning Strategies for Interactive Lecture | Center for Transformative Teaching | Nebraska. (2024). Unl.edu. https://teaching.unl.edu/resources/interactive-lecture/
4) Ahmad, M. (2023). Effect of Collaborative Learning on Conceptual Understanding ability in Mathematics among 5th Grade Neglected Children. Annals of Human and Social Sciences, 4(II). https://doi.org/10.35484/ahss.2023(4-ii)19
5) Akram, M. (2019). Relationship between Students' Perceptions of Teacher Effectiveness and Student Achievement at Secondary School Level. Bulletin of Education and Research, 41(2), 93–108. https://eric.ed.gov/?id=EJ1229453
6) Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual Understanding, Procedural Knowledge and Problem-Solving Skills in Mathematics: High School graduates work analysis and Standpoints. https://eric.ed.gov/?id=EJ1239165
7) Angraini, L. M., Kania, N., & Gürbüz, F. (2024). Students' Proficiency in Computational Thinking Through Constructivist Learning Theory. International Journal of Mathematics and Mathematics Education, 45–59. https://doi.org/10.56855/ijmme.v2i1.963
8) Aprilia, C. (2024). Cognitive Learning Theory: Skill Acquisition and Conditional Knowledge. Psikologiya Journal, 1(2). https://doi.org/10.62872/0y4sm303
9) Brookhart, S. M. (2021). *How to give effective feedback to your students* (2nd ed.). ASCD.
10) Charles, C. (2020). Comparing the effects of two inquiry-based teaching strategies on secondary students' conceptual understanding and achievement in mathematics: A mixed-methods approach. https://doi.org/10.7939/r3-r5p5-6x61
11) Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science, 24*(2), 97–140. https://doi.org/10.1080/10888691.2018.1537791
12) Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. Proceedings of the National Academy of Sciences, 116(39), 19251–19257. https://doi.org/10.1073/pnas.1821936116

13) Delgado-Rebolledo, R., & Zakaryan, D. (2019). Relationships between the knowledge of practices in mathematics and the pedagogical content knowledge of a mathematics lecturer. International Journal of Science and Mathematics Education, 18(3), 567–587. https://doi.org/10.1007/s10763-019-09977-0
14) Donlan, C. (2021). The development of mathematical skills. In Psychology Press eBooks. https://doi.org/10.4324/9781315784755
15) Dugay, P. M., & Pasia, A. (2023). An Open-Ended Approach in Developing Students' Proficiencies in Geometry. International Journal of Open-Access, Interdisciplinary & New Educational Discoveries of ETCOR Educational Research Center (iJOINED ETCOR), Volume II (2023)(Issue 3, P-ISSN – 2984-7567; E-ISSN-2945-3577). https://etcor.org/storage/iJOINED/Vol.%20II(3),%20658-682.pdf
16) Espinoza-Vásquez, G., Verdugo-Hernández, P., & Henríquez-Rivas, C. (2025). Relationships between domain changes and connections: An analysis from the perspective of mathematical work and teacher knowledge. European Public & Social Innovation Review, 10, 1–21. https://doi.org/10.31637/epsir-2025-1460
17) Etcuban, J. O., Peteros, E., Gamboa, A., Dinauanao, A., Sitoy, R., & Arcadio, R. (2019). Factors affecting mathematics performance of junior high school students. I nternational Electronic Journal of Mathematics Education, 15(1). https://doi.org/10.29333/iejme/5938
18) Gates, S. (2019). A Comparison of Cooperative Learning and Collaboration in High School Geometry Classes Including Geometry in Construction. Digital Commons@NLU. https://digitalcommons.nl.edu/diss/355/
19) Gillies, R. M. (2019). Promoting academically productive student dialogue during collaborative learning. International Journal of Educational Research, 97, 200–209. https://doi.org/10.1016/j.ijer.2017.07.014
20) Gulkilik, H. (2020). Analyzing preservice secondary mathematics teachers' prompts in dynamic geometry environment tasks. Interactive Learning Environments, 1–16. https://doi.org/10.1080/10494820.2020.1758729
21) Gurmu, F., Tuge, C., & Hunde, A. B. (2024). Effects of GeoGebra-assisted instructional methods on students' conceptual understanding of geometry. Cogent Education, 11(1). https://doi.org/10.1080/2331186x.2024.2379745
22) Hamidah, H., Zaenuri, Z., Isnarto, I., & Agoestanto, A. (2025). Self-investigation exercises: geometry learning strategies for prospective teacher students. Journal of Education and Learning (EduLearn), 19(2), 814–830. https://doi.org/10.11591/edulearn.v19i2.21012
23) Hattie, J., & Donoghue, G. M. (2023). Visible learning: The sequel. Routledge.
24) Herawati, H., & Sidik, G. S. (2023, June 29). Problem-Based learning to enhance pupils' conceptual understanding in geometry. https://ejournal.papanda.org/index.php/ijarme/article/view/469
25) Hershkowitz, R. (2020). Shape and Space: Geometry Teaching and Learning. *Springer EBooks*, 774–779. https://doi.org/10.1007/978-3-030-15789-0_138
26) Horn, I., & Garner, B. (2022). Teacher Learning of Ambitious and Equitable Mathematics Instruction. In Routledge eBooks. Informa. https://doi.org/10.4324/9781003182214
27) Hwang, J., & Ham, Y. (2021). Relationship between Mathematical Literacy and Opportunity to Learn with Different Types of Mathematical Tasks. Journal on Mathematics Education, 12(2), 199–222. https://eric.ed.gov/?id=EJ1312949
28) Hwang, W.-Y., Lin, Y.-J., Hoang, A., Rio Nurtantyana, & Lin, O. (2022). Facilitating Geometry Learning Through Real-Time Collaborative Activities with Augmented Reality in Authentic Context. Lecture Notes in Computer Science, 79–87. https://doi.org/10.1007/978-3-031-15273-3_9
29) İbili, E., Çat, M., Resnyansky, D., Şahin, S., & Billinghurst, M. (2019). An assessment of geometry teaching supported with augmented reality teaching materials to enhance students' 3D geometry thinking skills. International Journal of Mathematical Education in Science and Technology, 51(2), 224–246. https://doi.org/10.1080/0020739x.2019.1583382
30) İlhan, A. (2021). The impact of Game-Based, modeling, and Collaborative learning methods on the achievements, motivations, and visual mathematical literacy perceptions. SAGE Open, 11(1). https://doi.org/10.1177/21582440211003567
31) Inganah, S., Darmayanti, R., & Rizqi, N. (2025). Problems, Solutions, and Expectations: 6C Integration of 21st Century Education into Learning Mathematics. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.5012200
32) Jablonski, S., & Ludwig, M. (2023). Teaching and Learning of Geometry—A Literature Review on Current Developments in Theory and Practice. Education Sciences, 13(7), 682. https://doi.org/10.3390/educsci130706824
33) Jäder, J., & Johansson, H. (2025). Exploring students' conceptual understanding through mathematical problem solving: students' use of and shift between different representations of rational numbers. Research in Mathematics Education, 1–18. https://doi.org/10.1080/14794802.2025.2456840

34) Kacmaz, G., & Dubé, A. K. (2022). Examining pedagogical approaches and types of mathematics knowledge in educational games: A meta-analysis and critical review. Educational Research Review, 35, 100428. https://doi.org/10.1016/j.edurev.2021.100428
35) Kania, N., & Juandi, D. (2023). Does self-concept affect mathematics learning achievement? Journal of Education and Learning (EduLearn), 17(3), 455–461. https://doi.org/10.11591/edulearn.v17i3.20554
36) Khasawneh, et. al (2022). Examining the effect of inquiry-based learning versus traditional lecture-based learning on students' achievement in college algebra. International Electronic Journal 0of Mathematics Education, 18(1), em0724. https://doi.org/10.29333/iejme/1271
37) Klang, N., Karlsson, N., Kilborn, W., Eriksson, P., & Karlberg, M. (2021). Mathematical Problem-Solving Through Cooperative Learning—The importance of peer acceptance and friendships. Frontiers in Education, 6. https://doi.org/10.3389/feduc.2021.710296
38) König, J., Blömeke, S., Jentsch, A., Schlesinger, L., née Nehls, C. F., Musekamp, F., & Kaiser, G. (2021). The links between pedagogical competence, instructional quality, and mathematics achievement in the lower secondary classroom. Educational Studies in Mathematics, 107(1), 189–212. https://doi.org/10.1007/s10649-020-10021-0
39) Lahann, P., & Lambdin, D. V. (2020). Collaborative Learning in Mathematics Education. Encyclopedia of Mathematics Education, 94–95. https://doi.org/10.1007/978-3-030-15789-0_23
40) Lee, S. (2021). -By-Nc-Nd 4.0 Student Success In Active Learning Classrooms Versus Traditional Lecture Classrooms For Community College Mathematics: A Quantitative Study A Dissertation By. https://doi.org/10.5281/zenodo.5081089
41) Lumbre, A. P., Beltran-Joaquin, M. N., & Monterola, S. L. C. (2023). Relationship between mathematics teachers' van Hiele levels and students' achievement in geometry. International Journal of Studies in Education and Science (IJSES), 4(2), 113-123. https://doi.org/10.46328/ijres.61
42) Luzano, J. F. P. (2023). The interplay of conceptual understanding and problem solving competence in mathematics. International Journal of Multidisciplinary Approach and Studies, 10(2), 89-96. https://www.researchgate.net/publication/369982234
43) Machaba, F., & Mangwiro, C. (2024). Teacher follow-up on learners' initial response to teacher questions. African Journal of Research in Mathematics Science and Technology Education, 28(1), 120–133. https://doi.org/10.1080/18117295.2023.2297127
44) Maknun, J. (2020). Implementation of guided inquiry learning model to improve understanding physics concepts and critical thinking skill of vocational high school students. https://eric.ed.gov/?id=EJ1256165
45) Mainali, B. (2021). Representation in Teaching and Learning Mathematics. International Journal of Education in Mathematics, Science and Technology, 9(1), 1–21. https://eric.ed.gov/?id=EJ1282034
46) Maqoqa, T. (2024). An Exploration of Learners' Understanding of Euclidean Geometric Concepts: A Case Study of Secondary Schools in the OR Tambo Inland District of the Eastern Cape. E-Journal of Humanities, Arts and Social Sciences, 658–675. https://doi.org/10.38159/ehass.2024557
47) Mutaqin, E. J., Salimi, M., Asyari, L., & Hamdani, N. A. (2021). Realistic mathematics education approach on teaching geometry in primary schools: Collaborative action research. Journal of Physics: Conference Series, 1987(1), 012031. https://doi.org/10.1088/1742-6596/1987/1/012031
48) Mutawah, M. A. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual Understanding, Procedural Knowledge and Problem-Solving Skills in Mathematics: High School Graduates Work Analysis and Standpoints. International Journal of Education and Practice, 7(3), 258–273. https://doi.org/10.18488/journal.61.2019.73.258.273
49) Nwafor, M. C., Tsoho, m., & Umar Abubakar Aliyu. (2023). Effect of collaborative learning strategy on students' interest in geometry among senior secondary schools in zaria metropolis, kaduna state, nigeria. Journal of Science, Technology and Mathematics Pedagogy, 1(2), 132–143. https://jostmp-ksu.com.ng/index.php/jostmp/article/view/74
50) Nikou, S. A. (2023). Student motivation and engagement in maker activities under the lens of the Activity Theory: a case study in a primary school. Journal of Computers in Education. https://doi.org/10.1007/s40692-023-00258-y
51) Noreen, R., & Rana, A. M. K. (2019). Activity-Based Teaching versus Traditional Method of Teaching in Mathematics at Elementary Level. https://eric.ed.gov/?id=EJ1229426
52) Oco, R. M. (2024). Factors Related to the Students' Performance in English-Science-Mathematics: Psychology and Education- A Multidisciplinary Journal. DOI: 10.5281/zenodo.10647509
53) Oco, R. M. (2022). Student's Exposure on Synchronous-Asynchronous-Tutorial Aided Distance Learning: Impact on Academic Performance in Mathematics. Global Scientific Journals. EOI: 10.11216/gsj.2022.01.57745

54) Ogunjimi, M. O., & Gbadeyanka, T. A. (2022). Effect of Guided Inquiry and Explicit-Instructional Strategies on lower basic students' academic performance in Mathematics. Indonesian Journal of Teaching in Science, 3(1), 23–32. https://doi.org/10.17509/ijotis.v3i1.54191
55) Otajonova ,S.Sh.. (2025). Interactive Methods in Teaching Mathematics to Primary School Students: Fostering Engagement and Conceptual Understanding. Pedagogik Tadqiqotlar Jurnali, 2(2), 84–87. http://www.wosjournals.com/index.php/ptj/article/view/449
56) Patac, A. J. V., Patac, L. P., & Crispo, N. E. (2022). Students' understanding of a geometric theorem: A case of grade 9 problem posing. JRAMathEdu (Journal of Research and Advances in Mathematics Education), 7(2), 105–115. https://doi.org/10.23917/jramathedu.v7i2.16394
57) Peace, O., Ajaja, O. P., & Kpangban, E. (2024). Comparative consequence of puzzle Cooperative Learning Tactic and lecture Instructional Tactic on learners' mathematics recall in schools in Delta State Nigeria. Creative Education, 15(02), 201–211. https://doi.org/10.4236/ce.2024.152012
58) Palisbo, J. T., Pilvera, E. D., & Baluyos, G. R. (2025). Implementing collaborative rotation strategy in teaching geometry to enhance class engagement. International Journal of Research and Innovation in Social Science, 8(12), 1254–1265. https://doi.org/10.47772/IJRISS.2024.8120105
59) Prewett, S. L., & Whitney, S. D. (2021). The relationship between teachers' teaching self-efficacy and negative affect on eighth grade U.S. students' reading and math achievement. Teacher Development, 25(1), 1–17. https://doi.org/10.1080/13664530.2020.1850514
60) Pujiastuti, H., & Haryadi, R. (2023). Enhancing Mathematical Literacy Ability through Guided Inquiry Learning with Augmented Reality. https://eric.ed.gov/?id=EJ1381221
61) Rosenshine, B. (2019). Principles of instruction: Research-based strategies that all teachers should know. American Educator.
62) Ruipérez-Valiente, J. A., & Kim, Y. J. (2020). Effects of solo vs. collaborative play in a digital learning game on geometry: Results from a K12 experiment. Computers & Education, 159, 104008. https://doi.org/10.1016/j.compedu.2020.104008
63) Sadikova Ikhbol Iskandarovna. (2025). Geometry science in education Interactive teaching from the methods use. Innovative developments and research in education, 3(35), 255–259. https://interoncof.com/index.php/cad/article/view/8035
64) Schwarz, B. B., Swidan, O., Prusak, N., & Palatnik, A. (2021). Collaborative learning in mathematics classrooms: Can teachers understand progress of concurrent collaborating groups? Computers & Education, 165, 104151. https://doi.org/10.1016/j.compedu.2021.104151
65) Shrestha, D. K. (2022). Collaborative approaches for teaching and Learning geometry. Ku.edu.np. https://hdl.handle.net/20.500.14301/141
66) Simbulas, V. G., Salva, E. T., & Simbulas, L. J. C. (2023). Online Teaching Competencies, Attitude Towards Mathematics and Academic Achievement of Grade 10 Learners in Geometry: a Path Analysis. East Asian Journal of Multidisciplinary Research, 2(7), 3015–3038. https://doi.org/10.55927/eajmr.v2i7.4947
67) Sugiatno, S., Ridwan, R., Sinaga, Y. D. K., & Nuban, A. (2025). Understanding Middle School Math: Cool Problems to Get Students Thinking and Connecting. Canadian Journal of Science, Mathematics and Technology Education. https://doi.org/10.1007/s42330-024-00339-9
68) Sunzuma, G., & Maharaj, A. (2020). In-service Secondary Teachers' Teaching Approaches and Views Towards Integrating Ethnomathematics Approaches into Geometry Teaching. Bolema: Boletim de Educação Matemática, 34(66), 22–39. https://doi.org/10.1590/1980-4415v34n66a02
69) Sunzuma, G.,Zezekwa, N., Gwizangwe, I., & Zinyeka, G. (2021).A comparison of the effectiveness of ethnomathematics and traditional lecture approaches in teaching consumer arithmetic: learners' achievement and teachers' views. https://eric.ed.gov/?id=EJ1321509
70) The Effectiveness of Guided Inquiry on Understanding Mathematical Concepts. (2022). ANP Journal of Social Sciences and Humanities, 3, 70–76. https://doi.org/10.53797/anp.jssh.v3sp2.9.2022
71) Thompson, P. W. (2020). Constructivism in mathematics education. In Springer eBooks (pp. 127–134). https://doi.org/10.1007/978-3-030-15789-0_31
72) Ting, C. (2022). The effectiveness of collaborative learning in enhancing student learning outcomes. Journal of Informatics Education and Research, 2(1). https://jier.org/index.php/journal/article/view/16
73) Uygun, T. (2020). An inquiry-based design research for teaching geometric transformations by developing mathematical practices in dynamic geometry environment. Mathematics Education Research Journal, 32(3), 523–549.

https://doi.org/10.1007/s13394-020-00314-1
74) Woods, P. J., & Yasemin Çopur-Genctürk. (2024). Examining the role of student centered versus teacher-centered pedagogical approaches to self-directed learning through teaching. Teaching and Teacher Education, 138, 104415–104415. https://doi.org/10.1016/j.tate.2023.104415
75) Wu, N., & Wang, J. (2022). Mathematics teaching and student algebra and geometry performances in Hong Kong, Chinese Taipei, and US. Educational Studies, 1–17. https://doi.org/10.1080/03055698.2022.2128993