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IMPACT OF MANIPULATIVE-BASED INSTRUCTION ON STUDENTS' CONCEPTUAL UNDERSTANDING OF BASIC GEOMETRY IN A SECONDARY SCHOOL

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Abstract:
This research assessed the impact of manipulative-based instruction on students' understanding of basic geometry using a quasi-experimental design with 84 Grade 7 students at a public high school in Cebu, Philippines, during the school year 2025-2026. The participants were divided into two groups: 42 participants in the experimental group were taught using manipulative-based instruction, while 42 participants in the control group were taught traditionally. Pretest and posttest scores were collected and analyzed using mean, standard deviation, paired t-test and t-test for independent samples. Results showed that both groups had fairly satisfactory performance during the pretest. During the posttest, the control group had satisfactory performance, while the experimental group had very satisfactory performance. Moreover, both groups showed a significant difference between the pretest and posttest scores of the participants. On the other hand, there was a significant mean gain difference on the pretest and posttest scores between

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the two groups, which indicates that the experimental group performs better than the control group. This means manipulative-based instruction helped students understand geometry concepts better than the traditional method. The study concludes that using manipulatives is an effective way to teach geometry because it gives students concrete and hands-on experiences with abstract ideas. It is recommended that teachers use manipulative-based strategies in teaching geometry and other math topics to improve students' learning and participation.

Keywords: manipulative-based instruction, basic geometry, quasi-experimental design, grade 7 students

1. Introduction

Mathematics is one of the foundations of human daily activities, such as building bridges, forecasting the weather, managing businesses, and even making everyday decisions (Sharma, 2021). More than just numbers and formulas, math is a language, a way of communicating ideas clearly, solving problems, and making sense of the world around us. Its symbols and structures may seem rigid at first, but they carry a kind of elegance that can be both logical and beautiful. For many, math is still seen as a subject reserved for geniuses or for those who spend their lives crunching numbers (Peteros, 2024). But that view is slowly changing. Today, mathematical thinking reaches far beyond the classroom. It's a tool for research, innovation, and discovery. It helps us ask better questions and find smarter answers. And whether we realize it or not, math quietly supports nearly every aspect of modern life (Peconcillo *et al.*, 2020).

The challenge now is how math is taught to the students in school. Much of what students encounter today is rooted in ideas developed over a century ago. To prepare them for the future, educators need to go beyond memorization and calculation (Trust *et al.*, 2023). There is a need to nurture curiosity, resilience, and critical thinking. That journey starts early, ideally in the formative years, when children are most open to exploring patterns, solving puzzles, and thinking creatively. Teaching math is not just about building intellect. It is about shaping how children see themselves as learners and problem-solvers. When educators help them develop confidence in their thinking, they are also helping them prepare for life. Because the sooner their minds are stretched and strengthened, the more equipped they'll be to face the challenges ahead, with clarity, courage, and a sense of possibility. Mathematics has grown far beyond the classroom, becoming essential across disciplines, from biology and chemistry to economics, history, and the arts (Silangan *et al.*, 2023). Its tools shape decisions in government, industry, and everyday life, often unnoticed by students. Despite its relevance, many learners fail to grasp how math affects personal finance, public policy, and risk management.

This gap poses a challenge for secondary education. While algorithmic fluency and abstract reasoning are important, they must be paired with meaningful, real-world applications. Concepts like projectile motion should not be taught in isolation but used to enrich understanding of algebra and geometry (Sokolowski, 2021). To foster deeper engagement, students need to see mathematics reflected in their interests and future goals. Integrating classroom content with real-world applications fosters not only the development of essential skills but also cultivates learners' confidence and dispositions for active, informed engagement in societal life (Peteros *et al.*, 2022).

The Program for International Student Assessment (PISA) is a well-known way to test and compare the quality of education systems around the world. It shows how well 15-year-olds do in arithmetic, reading, and science, which gives an idea of how ready they are to deal with problems in real life (Alatli, 2020). Although the Philippines has regularly taken part in PISA, the results have consistently shown serious gaps in student achievement, especially in mathematics. These gaps point to deeper, long-standing issues in the country's education system that need thorough investigation and targeted interventions.

In response to these concerns, this research aims to address a key gap in existing literature by offering a comprehensive analysis of the various factors that affect students' performance in mathematics. While earlier studies have discussed general challenges in Philippine education, such as limited funding, outdated learning materials, and issues in teacher training, there has been less focus on how these problems specifically impact math learning (Luzano, 2024). By examining these factors more closely, the study hopes to uncover the root causes of the country's low PISA scores in math and help shape more effective strategies for improving math education nationwide.

In the Philippines, only a small number of students were able to show basic skills in mathematics, placing the country below the global benchmark for student performance. At this level, learners are expected to solve everyday problems such as comparing sizes, reading simple measurements, or converting money. This highlights a gap in foundational understanding that affects how students engage with more complex math concepts later on. In contrast, students from several high-performing education systems consistently reached or exceeded this level, with many demonstrating strong skills in advanced mathematical tasks. The difference in outcomes suggests a need to strengthen early math instruction and provide more support for conceptual learning, especially through approaches that make math more relatable and hands-on (Tessema *et al.*, 2024).

It is in this context that the researchers need to determine whether using manipulative-based instruction is truly effective in helping students grasp the basic concepts of Geometry. To do this, the strategy must be tested by implementing it in the classroom and comparing the performance of two groups: one learning with manipulatives and the other through traditional teaching methods. Moreover, this study aims to explore ways to strengthen students' foundational skills in Math and to find out whether using manipulative-based instruction in teaching basic Geometry concepts can boost their confidence and improve their understanding. Thus, the success of this research could help parents of struggling students better understand the basic concepts in Geometry, concepts that are highly useful in real-life situations.

2. Purpose of the Study

This research assessed the effectiveness of manipulative-based instruction on Grade 7 students' understanding of the basic concepts in Geometry at a public high school in Cebu, Philippines, for the school year 2025-2026. Specifically, this study sought to answer the following objectives:

1) To determine the level of the participants' performance during the pretest,
2) To determine the level of the participants' performance during the posttest,
3) To test the difference between the pretest and posttest scores of two groups,
4) To test the mean gain difference on the pre-test and post-test scores between the two groups.

3. Materials and Methods

This research utilized a quasi-experimental design using a non-equivalent two-group design wherein one group was exposed to manipulative-based instruction while the other was exposed to traditional teaching. A quasi-experimental design bridges the structure of true experiments, which involve random assignment to control and intervention groups (Hulley *et al.*, 2013), and the flexibility of observational research (Maciejewski, 2018). There were 84 participants in this study who were the Grade 7 students from a public high school. Informed consent was obtained from every participant before they were allowed to participate in the study. Furthermore, they were informed of their right to withdraw at any time when they no longer feel comfortable with the process. The distribution of the participants is presented in Table 1.

Table 1: Distribution of the Participants

Group	**n**	**%**
Control	42	50.00
Experimental	42	50.00
Total	**84**	**100.00**

The researchers utilized a 40-item Achievement Test to assess students' mastery of basic Geometry concepts in Grade 7, specifically aligned with the MATATAG Curriculum of the Department of Education. The instrument was administered in two phases: a pre-test conducted before the integration of mathematical manipulatives, and a post-test given after the intervention. This structure allowed for a clear comparison of students' performance before and after the use of hands-on instructional tools. The exam includes 40 multiple-choice items that assess key geometry skills aligned with the MATATAG Curriculum. The test underwent expert validation by content specialists and experienced Grade 7 mathematics teachers to ensure content validity, clarity, and curriculum alignment. The data gathered were treated using frequency count, percentage, weighted mean, standard deviation, paired t-test, and t-test for independent samples.

4. Results and Discussion

This section presents the results of the data gathered during the pretest and the posttest conducted to the two groups. This also includes the test of the difference between the pretest and posttest scores for the two groups and the test for the mean gain difference between the two groups.

4.1 Performance Level of the Two Groups during the Pretest

The study involved two sets of participants: one assigned to traditional instruction and the other to manipulative-based learning. Before starting the lesson on Basic Geometry, both groups took a multiple-choice pre-test. This test was given to check their readiness and how much they already knew about the topic. It also helped the researcher get a clear picture of where the students were starting from.

Table 2 shows that before the new teaching approach was introduced, both groups of students showed limited understanding of basic Geometry, as seen in their low scores on the first test. About 90% of students in the experimental group and roughly one-third of the control group reached the Fairly Satisfactory level, whereas a few were marked as Poor. No students from either group reached the top performance levels. The average scores, 9.83 for the comparison group and 11.17 for the group with the intervention, suggest that many learners had difficulty grasping key Geometry ideas like angles, shapes, and area, especially when it came to reasoning through measurement.

Table 2: Level of Performance of the Two Groups during Pretest

Level	Ranges of Scores	Control		Experimental	
		f	%	f	%
Outstanding	33-40	0	0.00	0	0.00
Very Satisfactory	25-32	0	0.00	0	0.00
Satisfactory	17-24	0	0.00	1	2.38
Fairly Satisfactory	9-16	29	69.05	38	90.48
Poor	0-8	13	30.95	3	7.14
Total		**42**	**100.00**	**42**	**100.00**
Average		9.83		11.71	
Standard Deviation		2.35		2.67	

This supports Bourne and Winstone's (2021) view that students need concrete experiences and active engagement to understand abstract concepts better. When learners are given the chance to explore ideas through hands-on activities, they are more likely to connect new knowledge with what they already know. This kind of active involvement helps them build stronger mental models and makes learning more meaningful. In the context of geometry, using manipulatives allows students to visualize and physically interact with shapes and relationships, which deepens their understanding and helps them move from simple observation to more complex reasoning.

3.2 Performance Level of the Two Groups during the Posttest

After the intervention, learners in the Experimental group showed notable progress. Most students (71.43%) reached the Very Satisfactory level, and 23.81% achieved Outstanding scores. On the other hand, while the Control group also improved, most of them (64.29%) stayed in the Satisfactory level. Only 19.05% reached Very Satisfactory, and none got Outstanding.

Table 3: Level of Performance of the Two Groups during the Posttest

Level	Ranges of Scores	Control		Experimental	
		f	%	f	%
Outstanding	33-40	0	0.00	10	23.81
Very Satisfactory	25-32	8	19.05	30	71.43
Satisfactory	17-24	27	64.29	2	4.76
Fairly Satisfactory	9-16	7	16.67	0	0.00
Poor	0-8	0	0.00	0	0.00
Total		**42**	**100.00**	**42**	**100.00**
Average		20.33		30.00	
Standard Deviation		4.70		3.52	

The average score for the experimental group increased to 30.00 (SD = 3.52), while the control group's average was 20.33 (SD = 4.70). These findings clearly show that using manipulative-based instruction made a big difference in students' understanding of geometry. This aligns with the work of Siller and Ahmad (2024), who found that combining concrete and virtual manipulatives significantly improved math achievement, including geometry, in a similar pre-post study. Their findings further support the idea that using a blend of hands-on and digital tools can cater to different learning styles and enhance students' understanding across various achievement levels. This adds more support to the idea that using manipulatives is a strong and flexible way to improve how students learn geometry in the classroom.

3.3 Test of Significant Difference between the Pretest and Posttest Scores in the Control Group

A test for significant difference between the pretest and posttest scores in the control group was conducted to determine if improvements were achieved using the traditional teaching method. This analysis shows whether the students' performance changed even without using manipulative-based instruction. The results also give a basis for comparing the two teaching methods.

Table 4: Test of Difference between the Pretest and Posttest Scores in the Control Group

Source of Difference	Mean	Standard Deviation	Mean Difference	t-value	p-value	Decision	Result
Pretest	9.83	2.35	10.50	15.677*	0.000	Reject Ho	Significant
Posttest	20.33	4.70					
*significant at p < 0.05 (two-tailed); df=41							

Table 4 shows the scores of the group that received regular classroom instruction before and after the lessons. Although their performance improved slightly, with an average increase of 10.50, the progress was modest. Still, the statistical results ($t = 15.677$, $p = 0.000$) show that this improvement was meaningful and unlikely to be due to chance. Because of this, the initial assumption that there would be no change was set aside. It reinforces the significance of applying hands-on and student-centered techniques in teaching Geometry. Although the control group demonstrated progress, the results suggest that students could achieve even more with approaches that promote active participation. Methods like manipulative-based instruction allow learners to learn through direct experience, which helps turn abstract theories into clear and usable knowledge. As supported by Freeman *et al.* (2014), shifting from passive lectures to active learning can lead to better outcomes, especially in subjects that require visualization and reasoning, like Geometry.

3.4 Test of Significant Difference between the Pretest and Posttest Scores in the Experimental Group

The test of significant difference between the pretest and posttest scores in the experimental group was done to find out if the manipulative-based instruction was effective. This study also examines whether the improvement in students' scores is real and not just by chance.

Table 5 presents the pre-test and post-test results of the experimental group exposed to manipulative-based instruction. The findings reveal a mean gain of 18.29, which is notably higher than the control group's gain. With a computed t-value of 27.623 and a p-value of 0.000, the results are also statistically significant, leading to the rejection of the null hypothesis.

Table 5: Test of Difference between the Pretest and Posttest Scores (Experimental Group)

Source of Difference	Mean	Standard Deviation	Mean Difference	Computed t- value	p-value	Decision	Remarks
Pretest	11.71	2.69	18.29	27.623*	0.000	Reject Ho	Significant
Posttest	30.00	3.52					

*significant at $p < 0.05$ (two-tailed); df=41

The substantial improvement suggests that manipulative-based instruction greatly enhanced students' conceptual understanding and retention of geometric concepts. According to Hattie & Zierer (2017), strategies that actively engage learners lead to stronger achievement gains. Similarly, Moyer-Packenham & Westenskow (2013) emphasized that manipulatives act as a bridge between abstract symbols and concrete representations, making mathematical ideas more accessible. This explains why the experimental group, who directly interacted with physical models, showed greater improvement compared to those taught using traditional strategies.

3.5 Test of the Significant Mean Gain Difference on the Pre-test and Post-test Scores between the Two Groups

The test of the significant mean gain difference between the pretest and posttest scores of the two groups was done to compare the effectiveness of the teaching methods used. The analysis examines if learners exposed to manipulative-based instruction achieved better results than those taught through conventional approaches. The results also show which method had a stronger effect on students' learning.

Table 6: Test of Mean Gain Difference

Source of Difference	Mean Gain	Standard Deviation	Mean Gain Difference	Computed t- value	p-value	Decision	Remarks
Control	10.50	4.34	7.79	8.268*	0.000	Reject Ho	Significant
Experimental	18.29	4.29					

*significant at $p < 0.05$ (two-tailed); df=82

Table 6 compares the average score improvements of the two groups. The group that used hands-on tools in their lessons showed a larger gain of 18.29, while the group that followed regular teaching methods had a smaller gain of 10.50. The results ($t = 8.268$, $p = 0.000$) show that this difference is meaningful and not just due to chance. In short, the students who learned through manipulative-based instruction made significantly better progress.

These results reinforce the value of manipulative-based learning in mathematics. Ahmad and Siller (2024) recently explored how combining physical and digital learning tools can support math achievement. Their study, which followed a before-and-after design, showed that students from diverse backgrounds made notable progress when both concrete and virtual manipulatives were used during instruction. Furthermore, Ponte *et al.* (2023) demonstrated that even simple exploring and building with geometric manipulatives helped elementary students better differentiate shapes and understand spatial properties (e.g., recognizing that a square is a rectangle, but not vice versa).

4. Conclusion

The findings of this research clearly indicate that instruction based on manipulatives significantly enhances the conceptual understanding of fundamental concepts in geometry among Grade 7 students. Before the conduct of the study, both the control and experimental groups demonstrated low performance levels, with most students categorized as fairly satisfactory, and none reaching exceptional levels in the pretest. Nevertheless, following exposure to instruction based on manipulation, the experimental group demonstrated significant progress, with most attaining highly satisfactory and exceptional levels in the posttest. Statistical evaluation reinforced this enhancement, showing notable differences between pretest and posttest results in both groups, yet with a markedly greater mean increase in the experimental group, suggesting enhanced learning development compared to those receiving conventional teaching. Similarly, the test of mean gain difference validated the superiority of manipulative-aided learning, showing a highly significant benefit for the experimental group. These results strongly indicate that employing concrete materials and practical learning experiences aids learners in visualizing concepts, enriches reasoning, and improves understanding, rendering geometry more approachable and significant. Consequently, teachers, curriculum designers, and educational institutions are urged to implement manipulative-focused teaching methods, particularly in areas related to spatial and geometric ideas, where visualization and engagement are crucial for understanding. The findings confirm that when students participate actively instead of passively absorbing information, their comprehension enhances, their performance gets better, and their confidence in mathematics rises. Consequently, instruction based on manipulation is a powerful teaching method that enhances conceptual understanding in geometry, and applying it in classrooms can significantly improve math performance, especially in junior high school, where essential concepts are vital for later learning.

Conflict of Interest Statement
The authors declare no conflicts of interest.

About the Author(s)
Catherine E. Carcueva is a Teacher I from Cebu, Region VII, specializing in Secondary Mathematics Education. She holds a Bachelor's Degree in Education major in Mathematics from Cebu Normal University. Her practice focuses on engaging diverse learners, applying innovative strategies, and fostering a positive, inclusive learning environment. She also participates in collaborative projects that support continuous improvement in her school and community. Her work reflects a commitment to helping

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Braian Basmayor is an educator and mathematics graduate committed to supporting student learning and academic growth. He completed his Bachelor's degree in Mathematics at Cebu Technological University–Danao Campus, where he developed a strong foundation in mathematical theory, problem-solving, and logical reasoning. He is currently serving as a Teacher I in the Division of Danao. In this role, he works closely with learners to help them build confidence and understanding in mathematics. His teaching approach is grounded in patience, clarity, and the belief that every student can succeed when given the right guidance and support. Beyond classroom instruction, he continues to strengthen his expertise by engaging in professional development and pursuing opportunities that enhance his teaching practice. His dedication reflects his goal of contributing to quality education in his community and fostering a positive learning environment for future generations.

Roselyn D. Boiser is a MAEd Mathematics student at Cebu Technological University–Main Campus with a strong interest in mathematics education. She is an educator who has been teaching Mathematics for 10 years at Biabas Trade High School, Ubay, Bohol, Philippines. Her academic training has strengthened her skills in using manipulatives for effective mathematics instruction and has deepened her commitment to producing meaningful and relevant research. Motivated by her dedication to quality mathematics education, she conducted this study to contribute to both scholarly understanding and practical application. She remains committed to further growth as a researcher and educator, guided by curiosity, integrity, and a desire to create positive impact.

Grace Fernandez Rabadon has been teaching Senior High School at General Climaco National High School for six years and before that she was a Junior High School teacher for seven years. She received a Bachelor's degree in Secondary Education with a major in Mathematics from Cebu Normal University. Now she is a grade 11 advisor and the school's guidance designate. Concurrently, she is writing her thesis for a Master of Arts in Teaching Mathematics at Cebu Technological University main campus. She is very interested in the research area of basic mathematics operations, particularly the students' knowledge retention and thus their success not only in a local but also international context. Her research investigates the incorporation of manipulative tools as teaching strategies for the purpose of concept acquisition in geometry. Her sheer enthusiasm for teaching mathematics leads her to test different methods that are fun, meaningful, and engaging in math classes, thus guaranteeing that students will develop their love and deep understanding of mathematics not only in the classroom but also outside.

Ritchie T. Saavedra holds an education degree. At Cebu Technological University-Main Campus, she is pursuing a Master of Arts in Education with a focus on teaching mathematics. She has taught mathematics in the public school system for twelve years and continues to do so now. She currently holds the positions of School Records In-charge and Class Advisor for pupils in Grade 7. Her professional background includes significant administrative expertise, particularly in the areas of school leadership and records administration, as well as academic proficiency in mathematics. This diverse background creates a strong foundation that informs and strengthens the depth, methodological accuracy, and usefulness of her educational research. Her objective in conducting this research was to advance both theoretical understanding and practical relevance.

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