Improving Grade 7 Students' Geometry Performance Using Manipulatives: A Study from a Jamaican Secondary School

Nicole Jacobs[1], Shaneille Samuels[2]

[1]Shortwood Teachers' College, Department of Mathematics, 77 Shortwood Road, Kingston 8, Jamaica
Email: *nickybryan[at]gmail.com*

[2]University of Technology, Papine Campus, Jamaica, School of Mathematics and Statistics, Faculty of Science & Sport, 237 Old Hope Road, Kingston 2, Jamaica
Email: *shaneille.samuels[at]gmail.com*

Abstract: ***This study explores the impact of manipulatives on improving mathematical understanding and performance among Grade 7 students in a Jamaican secondary school. Using purposive sampling, eleven male students aged 11 to 13 were selected to assess learning outcomes in geometry. Pre- and post-intervention data revealed that 64% of students demonstrated improved test scores following manipulative-based instruction. While the strategy particularly benefited underperforming learners, it did not yield uniform results, with 27% showing no change and 9% experiencing a decline. Nonetheless, all students engaged actively with the material, underscoring the motivational value of hands-on tools. The study concludes by emphasizing the importance of differentiated instruction and suggests that manipulatives, when aligned with student needs, can be a valuable component in mathematics education.***

Keywords: manipulatives, geometry education, mathematical understanding, secondary school mathematics, conceptual learning

1. Introduction

During my teaching practicum at an all-boys school, I observed that Grade 7 students faced challenges in mathematics, despite the curriculum being revised to support a spiral learning approach. This may be partly attributed to the impact of the COVID-19 pandemic, which reduced in-person instruction and prompted a shift to online learning, resulting in considerable content gaps. Some students demonstrated weaknesses in fundamental areas such as memorizing multiplication tables and basic multiplication and division skills. Many students expressed a dislike for mathematics, some even stating that "the subject didn't like them." I also noted that some students were restless and had limited conflict resolution skills, an area I dedicated time to addressing. Despite these efforts, their mathematical performance remained below the teacher's target of 60%, highlighting the urgent need for intervention to meet the Grade 7 Mathematics Curriculum objectives. Recognizing that the students were very active and kinesthetically inclined, I decided that incorporating manipulatives might be an effective strategy to improve their performance. It was also apparent that while students could verbally explain some concepts, they struggled when asked to read and answer questions from a paper.

In particular, over the years, students have shown significant challenges in comprehending both algebraic concepts and geometric topics, which are foundational strands for grade 7 students to progress in mathematics. Collins *et al.* [1] shared in their study that students showed signs that they struggled to understand concepts such as solving simple equations, identifying patterns, using variables, identifying properties of shapes, and estimating angles. In other words, students have major difficulty with abstract reasoning and visual spatial thinking, which are demanded for students to develop conceptual understanding.

These Grade 7 students had recently completed the Primary Exit Profile (PEP), Jamaica's national Grade Six examination, which assesses student performance and determines high school placement to the Secondary level. The students are tested in the following areas: Abilities, Mathematics, Language Arts, Social Studies, and Science. The exams were graded on the following scale, beginning, developing, proficiency and high proficiency with the exception of Abilities where the raw score is used. The Jamaica's former Minister of Education Mrs. Fayval Williams, in 2023 reported that 57% of students achieved proficiency or high proficiency in Mathematics in the 2023 PEP Exams which was an improvement in comparison to previous years [2]. However, she stated that the Exam had been tweaked during the 2020-2022 periods to accommodate the impact of the COVID-19 Pandemic on learning. She also reported that the girls outperformed boys in mathematics [2]. Although the PEP results revealed that almost 60% of students were at the Grade 6 level, the teacher researcher did not notice this during observations of the incumbent Grade 7 students who may have come from that batch of Grade 6 students. The teacher-researcher would like to have at least 80% of students achieving good performance levels of 70% or higher. The teacher researcher was also concerned about the students' future achieve academic success if their challenges with mathematics was not addressed. The Organisation for Economic Cooperation and Development (OECD) Programme for International Student's Assessment (PISA) tests the skills and knowledge of 15-year-olds in mathematics, reading and science. The 2022 PISA tests had eighty-one countries participating in the assessment which focused on mathematics. The PISA results revealed that Jamaican students' mathematics average was 43% while the overall PISA mathematics average was 69% [3].

Another major concern of the teacher-researcher, having previously worked in the private sector within the service industry, observed a recurring challenge during the hiring process: a significant number of job applicants lacked a passing grade in CXC CSEC Mathematics. This deficiency often resulted in individuals being overlooked for employment opportunities or being confined to positions that were below their qualifications or career aspirations. Such limitations not only hindered their professional advancement but also affected their confidence and motivation as most of them seem embarrassed by this failure. This trend raised critical concerns for the teacher-researcher, prompting questions about the underlying causes within the education system that contribute to the high rate of mathematics underachievement. The consistent pattern of poor mathematical performance among school-leavers entering the workforce highlights a potential gap in teaching strategies, curriculum effectiveness, or student engagement, all of which warrant deeper investigation. The Prime Minister of Jamaica, Dr. The Most Honourable Dr. Andrew Holness stated that “The country cannot develop with us not doing better at mathematics” [4]. In that same article he also pointed out that the better paying jobs are in the areas of science, technology, engineering and mathematics. He said this in response to the disappointing 33.4% pass rate for CXC CSEC mathematics results in 2024 [4]. The reality is that mathematics serves as a foundational skill for both academic success and employability. It is therefore essential to understand the challenges that students face in mathematics and to provide intervention for improving leaning outcomes and workforce readiness.

Purpose of the Study

This study aimed to explore the specific challenges faced by Grade 7 students in mathematics and to evaluate the effectiveness of manipulatives in improving their understanding of geometrical concepts and overall mathematical performance.

Significance of Study

This study aimed to explore the specific challenges faced by Grade 7 students in mathematics and to evaluate the effectiveness of manipulatives in improving their understanding of geometrical concepts and overall mathematical performance.

Research Questions

1) What key challenges do Grade 7 male students in Jamaica face when learning geometric concepts in mathematics?
2) To what extent does the use of manipulatives enhance Grade 7 students’ conceptual understanding and problem-solving abilities in geometry?

Definition of Terms

Mathematical Performance – This refers to the ability to “formulate, employ and interpret mathematics in a variety of contexts to describe, predict and explain phenomena, recognising the role that mathematics plays in the world” [3]. In the context of this study, mathematical performance is defined as students demonstrated ability to understand and apply mathematical concepts, whether assessed formally or informally. This includes their performance in written assessments and other mathematical activities where they are expected to apply what they have been taught.

Manipulatives – According to Larbi & Okeyere [6] manipulatives are materials from our own environment that learners can use to learn or form mathematical concepts. These materials help the students to understand Mathematics by reducing the abstract nature of Mathematics. Manipulatives are objects that are used in Mathematics to engage students in learning concepts and can either be physical object or virtual object. In this study the teacher-researcher used physical manipulatives otherwise known as concrete manipulatives.

Conceptual Understanding in Mathematics – Conceptual knowledge is defined as an “understanding of the underlying structure of mathematics—the relationships and interconnections of ideas that explain and give meaning to mathematical procedures” [7].

In this study, conceptual understanding refers to students’ ability to grasp mathematical ideas deeply enough to apply them confidently in real-life situations and academic assessments. Developing conceptual understanding often leads to increased confidence and improved mathematical performance.

2. Literature Review

This section explores the key theoretical and practical foundations that inform this study, with a focus on enhancing mathematics education. Grounded in Constructivist Learning Theories, the study draws on the work of Jerome Bruner’s *Three Modes of Representation* and Lev Vygotsky’s *Sociocultural Theory*, which together provide a framework for understanding how students construct knowledge through experience and social interaction. These theories support the idea that learning is most effective when students are actively involved in making sense of mathematical ideas, particularly through hands-on and collaborative experiences.

Bruner’s Three Modes of Representation

Bruner proposed a framework for how students learn, which applies to mathematics, especially when introducing new mathematical concepts to students. This framework includes three sequential modes of representation; namely Enactive, Iconic, and Symbolic Phases respectively [8, 9]. The following gives details of each phase and an example activity to support it.

- *Enactive/ Actively Phase* - In this stage, the child or learner needs to interact with the concrete materials to understand the concept. This allows students to engage in hands-on mathematics activities by physically manipulating objects, helping them internalise abstract mathematical concepts. For instance, Jane Currell [10] shared that she taught students a lesson on equivalent fractions where she used multi-link cubes. She used the cubes to help students visualize the fractions and physically represent them. For example, five cubes were used to engage students in a hands-on activity: three blue cubes represented $\frac{3}{5}$, and two green cubes represented $\frac{2}{5}$. This visual model helped students understand that the two representations could not be considered equivalent, as the groupings (or arrangements) were not the same. This allowed the students to see and touch physical representation of the fractions, rather than relying solely on symbolic representations. This tangible experience allows students to recognize the relationship between numerators and denominators to develop a foundational understanding of fractions, which abstract teaching methods, when used alone, fail to achieve.

- *Iconic Phase* - child/teacher then creates a visual representation or a picture of the activity, where the teacher includes demonstrations/ illustrations. For instance, Currell [10] shared that her students after using the multilink cubes for fractional representations, then engaged in drawing pictures. There are two pictures, one above the other, where one shows a whole (representing 5 parts) and above that picture, there is another showing the division of the whole into three and two parts to represent $\frac{3}{5}$ and $\frac{2}{5}$. This presentation was done using the bar model for easier comparison.
- *Symbolic Phase* - The learner uses mathematical symbols to represent the scenario. For example, $\frac{3}{5}$ and $\frac{2}{5}$ are symbolic representations used to show the tangible and pictorial representations of the fractions. Additionally, they could deduce the whole by adding $\frac{3}{5}$ and $\frac{2}{5}$ using mathematical symbols: $\frac{3}{5}+\frac{2}{5}=\frac{5}{5}=1$.

The Concrete-Representational-Abstract (CRA) approach closely aligns with Jerome Bruner's three modes of representation, offering a structured pathway for developing mathematical understanding. The concrete stage mirrors Bruner's enactive mode, where learners physically manipulate objects to grasp concepts. The representational stage corresponds to the iconic mode, involving visual or pictorial representations to support thinking. Finally, the abstract stage aligns with the symbolic mode, where learners use mathematical symbols and notation to demonstrate understanding without relying on physical or visual aids. This progression supports cognitive development by building conceptual understanding before moving to formal abstraction and ultimately leading to improved mathematical performance. The study by Larbi & Okeyere, [6] on the 'Use of Manipulatives in Mathematics Education' investigated the effectiveness of using algebra tiles on the mathematical performance of 56 junior high school students in Ghana from two schools split into a control group and an experimental group. The study revealed that students in the experimental group who were taught algebra units over four weeks using algebra tiles outperformed their counterparts in the controlled group.

Lev Vygotsky's Sociocultural Theory

Lev Vygotsky's sociocultural theory explains that students learn best when they interact with others, especially those who already understand a topic well. He believed that learning starts through social interaction and becomes part of the student's own thinking over time. One important idea in his theory is the Zone of Proximal Development (ZPD), which is the difference between what a student can do alone and what they can do with help. In the classroom, this means students can solve harder problems in math when they get support from a teacher or a classmate [11]. Vygotsky also believed that language helps students think and solve problems, making it an important part of learning. By integrating this knowledge of the ZPD, educators can be guided to impart literacy skills, peer teaching or utilization of activities with peers group to assist students to improve mathematical performance.

2.1 The Challenges Impacting Students' Mathematical Performance

This section examines the multifaceted challenges affecting students' mathematical performance, with a particular focus on the Jamaican context, through a review of relevant literature. Key issues identified in the research include lack of prior knowledge, frequent absenteeism, students' negative attitudes toward mathematics, math anxiety, and difficulties in understanding algebraic and geometric concepts. These factors contribute to learning gaps and hinder students' academic progress. The literature also highlights how math anxiety can undermine students' confidence and willingness to engage with mathematical tasks, while gaps in foundational knowledge and persistent struggles with abstract concepts—such as algebra and geometry—further compound their difficulties.

Lack of Prior Knowledge

Dong *et. al.* [12] conducted a study in China on 356 students' ages 12–15 years to investigate if prior knowledge influences engagement of students; they included mathematics classes. The research showed that prior knowledge had a positive impact on learning engagement, and the researcher realised that many students in this study had an aversion to mathematics. The study also revealed that students with low levels of prior knowledge were less likely to seek help during the learning process compared to their counterparts with higher levels of prior knowledge. This situation can lead to a continued cycle of poor performance if no intervention takes place. The teacher-researcher also experienced this in some instances while in the Grade 7 class. What is evident in both the study identified above and the teacher-researcher's experience is that pre-existing situations did influence the teaching and learning experience, which in turn impacts mathematical performance.

Dislike of Mathematics

A study by Gafoor & Kurukkan [13], in India explored the reasons high school students found mathematics difficult. Their study of 51 students (25 boys and 26 girls) found that 88% of students reported that Mathematics was the subject they hated the most. The main reason given for not liking mathematics was that they found it a difficult subject. Oftentimes, students expressed that it is difficult due to the abstract nature of mathematics, especially when they find it hard to relate to real life contexts. In fact, the study reported that those students who dislike mathematics tend to have a negative self-efficacy for learning mathematics. This indicates that students lack confidence in their mathematics ability which not only cause them to become disengaged but also become part of a continuous cycle where they avoid anything that requires mathematics and thus perform poorly. Consequently, students can become anxious and unwilling to complete problem-solving tasks, which may widen their learning gaps even more.

Absenteeism

Absenteeism in schools refers to the consistent or habitual absence of a student, whether excused or unexcused, which disrupts learning and negatively impacts academic performance. Chronic absenteeism—defined as missing 10% or more of the school year for any reason—has been closely linked to lower academic achievement, particularly in mathematics [14]. García & Weiss [14], in their study, covering data from 2003 to 2018, emphasizes the long-term consequences of missed instruction. In Jamaica, ongoing student absences continue to hinder mathematics achievement, along with other subjects [15]. The Minister of Education, Skills, Youth & Information Senator Dr. the Honourable Dana Morris Dixon expressed that absenteeism is a big deal in Jamaica affecting Jamaica's goal of ensuring equity and transformation of the education sector [15]. She expressed that students cannot succeed in learning if they are not even present. Moreover, since mathematics is a cumulative subject, even brief absences during foundational lessons can create knowledge gaps that impede later understanding and problem-solving. This issue is especially severe in Grade 7 classrooms who are just transitioning from primary schools, particularly when there are large class sizes and limited individualized support make it harder for struggling students to catch up. The Jamaican public school system currently enrolls over 400,000 students across primary and secondary levels [16]. During the COVID-19 pandemic, nearly 120,000 enrolled students were unaccounted for, receiving little or no instruction for almost two years. This led to significant learning loss and retention issues [16].

Mathematics Anxiety

Another challenge that impacts mathematical performance is mathematics anxiety. Richardson and Suinn [17] as cited by Rugg & Boes [18] defined "math anxiety as stress causing negative physical reactions that interfere with the manipulation of numbers and problem solving in both academic settings and everyday life". Math Anxiety is a confirmed medical condition. The impact of poor performance in Mathematics in the form of anxiety is very real. In one study of over one million students [19], revealed that countries with higher levels of mathematics anxiety lead to lower math grades in students. The anxiety extends not only to the individual students but to peers sometimes even leading to an entire nation experiencing it. Interestingly, one study conducted in 2018 reported by Geddes [19] found that 77% of children with high math anxiety were normal to high achievers. It is possible to have math anxiety and still perform well in mathematics. In Jamaica, however, a cross-sectional study conducted by Collins *et al.* [1] across six high schools, involving Grade 8 and Grade 9 students, examined the impact of learning-based activities, algebra tiles, and problem-solving teaching strategies on students' conceptual understanding of mathematics. The study employed the Modified Abbreviated Math Anxiety Scale (mAMAS) and found that 25% of the participants reported experiencing negative emotions toward mathematics, indicating a significant presence of math anxiety among early secondary students. The population of this study also fits into the early secondary students' category. Collins *et al.* [1] went further to share that some students panic once they realize the mathematics tasks are unclear to them; while others shut down from participating and answering questions whenever they get incorrect answers for questions.

Geometry Challenges in the Jamaican Setting

The study by Collins *et al.* [1] focused on the Jamaican secondary school contexts highlighting the challenges students encountered in mastering conceptual understanding of algebraic and geometric concepts. The study revealed that 75% of the students had difficulty understanding algebraic and geometric concepts, 36% struggling particularly with problem-solving, especially when it came to worded problems. The study indicated that students struggled to translate worded problems into visual representations of geometric concepts, partly due to unfamiliarity with terms such as 'hinges' and 'trapdoor.' This lack of vocabulary later contributed to difficulties in solving problems involving angles and measurement. According to Collins et al. [1], the teacher-researchers reported that although CXC has encouraged teachers to incorporate real-world problems—particularly in geometry, measurement, and algebra, which are the areas students struggle with most—there is insufficient time to explore these types of worded problems in depth.

2.2 The Impacts of the Problem

The study reviewed literature that focuses on the significant impacts of students' poor mathematics performance, with a particular insight into their overall development and prospects. In this section, low self-esteem, diminished self-confidence, poor examination readiness, and limited range of career paths were highlighted. Oftentimes, students who struggle with low self-esteem and diminished self-confidence tend to struggle with their academic outcomes, repeatedly impacting their examination readiness. Also, when these issues persist, students tend to be constrained in their career paths, especially when passing mathematics is necessary for some fields. This can hinder them from their long-term aspirations and socioeconomic mobility.

Low Self-Esteem and Self-Confidence

One impact of poor academic performance is low self-esteem in one's academic ability. Poor performance in anything can lead to low self-esteem and continued poor performance. The article "Study: Bad Marks in Mathematics" reported that in a study conducted in Finland by the University of Jyvaskyla of 560 children between the ages of 10 - 13 years old and in the grade 4 - 7 revealed that lower marks in Maths lowered self-esteem for both boys and girls [20]. The researchers had found that the awarding of numerical grades in class made students compare their own achievement with those of their classmates which can lead to feelings of inferiority [20]. The study also reported that students who performed at higher levels in Mathematics had higher self-esteem. Pekrun et al. [21] as cited by Aguilar [22] conducted a longitudinal study about the relationship between emotions and achievement found that there is a relationship between types of emotions and the level of achievement. The study also revealed that positive emotions the higher the math scores and the lower the emotions the lower the math scores and performance. Aguilar [22] study revealed that in order to overcome negative emotions and low mathematics performance teachers should be encouraged to help their students realize that success and achievement are not linked to their perception of how capable (or not) they are to perform well but success overall is the result of working toward a goal. He emphasizes that teachers should help students to understand that struggling to do something like Mathematics is ok and is a part of learning. This approach would mitigate low self-esteem in students and change their mindset towards mathematics.

Poor Examination Readiness and Limited Career Path

Dr. Wayne Wesley, Registrar and CEO of the Caribbean Examinations Council (CXC), has highlighted a troubling trend across the Caribbean region: many students are failing to qualify for university admission due to poor performance in Mathematics and English. According to Wesley, since 2018, approximately 11,500 students each year have not passed both subjects, making them ineligible for tertiary education [22]. As a result, many of these students are left with limited options and often settle for low-paying jobs, diverting them from their intended career paths. This issue points to a larger concern about students' readiness for high-stakes examinations. Contributing factors may include gaps in foundational knowledge, lack of access to adequate study resources, ineffective teaching strategies, and poor study habits. Without proper preparation and support, students are ill-equipped to meet the academic demands of national examinations, ultimately limiting their future opportunities.

2.3 Strategies to Manage the Problem

This section outlines practical strategies that can be used to address students' mathematical performance based on the persistent challenges students encountered. The literature highlights that manipulatives can be used to address conceptual understanding issues, while discovery-guided learning allows students to actively engage with content and think critically. Another strategy is the integration of technological tools to improve students' interaction and visualization of concepts. Together, these strategies enable students to benefit from deeper learning and the potential enhancement of their mathematics performance.

Use of Manipulatives

Manipulatives are widely recognized for their effectiveness in enhancing conceptual understanding and improving mathematical performance. Grounded in Bruner's 1966 enactive mode of representation, manipulatives support active, hands-on learning by allowing students to physically engage with mathematical ideas before transitioning to more abstract forms [10]. This developmental approach not only improves comprehension but also increases student motivation and confidence. Research by Hidayah et al. [24] found that students taught with manipulatives scored significantly higher on post-tests compared to those taught using traditional methods, with an average performance increase of 22%. Their findings also indicated that manipulatives enhanced classroom engagement and encouraged active problem-solving. Likewise, Cockett and Kilgour [25] reported that 87% of students surveyed felt that manipulatives made learning mathematics easier and more enjoyable, with many indicating a clearer understanding of abstract concepts through hands-on exploration. As seventh-graders transition into the formal operational stage (Piaget's theory) of cognitive development, which is characterized by the ability to think abstractly manipulatives may be ineffective. Hurst and Linsell [26] shared that a major meta-analysis of lessons of multigrade levels K – College level, was done by Puchner *et al.* [27] which found that manipulatives can be also ineffective. At the grade 6 level students were given manipulatives to work on 2 x 2 digit multiplication and were unable to use the manipulatives but could just apply standard procedures. The use of manipulatives should be taught and the manipulative should be applicable. Puchner *et al*. [27] as cited by Hurst and Linsell [26] also noted that "teachers often use manipulatives in a procedural manner, instructing students to apply a manipulative to obtain a correct answer. Such use obstructs, rather than helps conceptual learning". In the context of this study, the teacher-researcher selected manipulatives as an intervention to address gaps in students' learning to boost overall mathematics achievement. However, challenges such as the need for substantial resource allocation and advanced lesson planning are some of the limitations in implementing manipulative-based instruction consistently.

Discovery-Guided Learning Strategy

An alternative instructional strategy to address the research problem is Discovery-Guided Learning, a constructivist approach that encourages students to actively explore, investigate, and draw conclusions about mathematical concepts through inquiry-based tasks. This strategy aligns closely with the principles of Jamaica's National Standards Curriculum (NSC), which promotes student-centred learning, critical thinking, and problem-solving skills which are key competencies emphasized in the Grade 7 mathematics framework [28]. Research by Amiyani and Widjajanti [29], which involved a meta-analysis of 16 studies conducted between 2011 and 2018, found that the implementation of Discovery-Guided Learning in mathematics led to notable academic gains: mathematical achievement improved by an average of 21%, conceptual understanding by 18%, and cognitive ability by 16%. Furthermore, the strategy was associated with increased student self-confidence and engagement, two factors strongly correlated with sustained academic performance in mathematics. Despite these benefits, one notable limitation is the time-intensive nature of the discovery guided learning strategy because students are encouraged to investigate, and test multiple solution paths before formal instruction, lessons can require more planning time and extended in-class engagement than traditional approaches. Given these constraints and the need to address immediate learning gaps within a fixed instructional timeframe, the student-researcher opted not to use Discovery-Guided Learning as the primary intervention in this study. Nonetheless, its alignment with Jamaica's competency-based curriculum framework underscores its long-term value for developing mathematical reasoning and learner autonomy.

Use of Technological Approach

The use of technology in mathematics instruction is another alternative for improving student performance, particularly at the lower secondary level. This approach involves integrating digital tools to enhance both conceptual understanding and student engagement, allowing learners to visualize abstract mathematical concepts more concretely. Through applications such as virtual manipulatives, graphing tools, and simulations, students can explore mathematical ideas in interactive and meaningful ways. Additionally, technology opens opportunities for collaborative learning, even across international classrooms, which can enrich students' global perspectives and problem-solving skills. This strategy aligns with constructivist learning theory, which emphasizes active, exploratory learning, and it supports the goals of Jamaica's National Standards Curriculum (NSC), which advocates the integration of Information and Communication Technology (ICT) to promote 21st-century learning skills [28].

A study conducted by Liburd and Jen [30] on the effectiveness of a technology-based approach in a Caribbean high school demonstrated the positive impact of using GeoGebra, a dynamic mathematics software. The study found that students who received instruction using this technological tool exhibited significantly higher levels of conceptual understanding compared to their peers who were taught using traditional methods. These findings reinforce the potential of educational technology to support deeper mathematical learning and improve student achievement. However, similar to other resource-intensive strategies, the effective integration of technology requires adequate infrastructure, teacher training, and classroom management skills, which may limit its feasibility in some educational settings. As such, while not selected as the primary intervention in the present study, technology-enhanced instruction remains a valuable long-term strategy for improving mathematics outcomes in Jamaican classrooms. Research on mathematical underachievement at the lower secondary level highlights several contributing factors, including lack of prior knowledge, mathematics anxiety, absenteeism, and low student engagement. These challenges often result in poor conceptual understanding, low self-esteem, and reduced confidence, ultimately affecting examination readiness and limiting future career opportunities. Theoretical frameworks such as Bruner's three modes of representation—enactive, iconic, and symbolic—and Piaget's stages of cognitive development underscore the importance of developmentally appropriate, hands-on learning experiences that support learners' transition from concrete to abstract reasoning, especially during early adolescence. As a response to these challenges, various strategies have been explored, including manipulative-based instruction, discovery learning, and technology integration, all grounded in constructivist learning theory. Of these, mathematical manipulatives have shown promise in enhancing student engagement, building conceptual understanding, and reducing anxiety by allowing learners to physically explore and internalize abstract ideas. However, there remains a limited body of research focused specifically on Grade 7 classrooms in Jamaica, and even fewer studies have been conducted in single-gender (all-boys) school settings, where additional motivational and behavioural factors may influence learning outcomes. This study aimed to address this gap by investigating the effectiveness of manipulatives in improving mathematical performance in a Grade 7 all-boys classroom, with the goal of informing more targeted, evidence-based interventions in similar educational contexts.

3. Methodology

3.1 Research Design

An action research method was chosen for this study to gain first-hand information from the subjects themselves (students) and to address the research problem. The teacher-researcher sought to use action research to explore and improve her instructional practice, as she engaged the students with the intent to respond to their needs. Parsons and Brown [31] as cited in NCTM [32] describes action research as a form of investigation designed for use by teachers attempting to solve problems and improve pedagogy in their classrooms by performing systematic observations and data collection which can be then used by the teacher-researcher in reflection, decision-making and the development of more effective classroom strategies. Thus, making action research especially relevant, where the teacher-researcher could iteratively test the applied instructional strategies and continuously refine time. The intervention plan for this study followed six consecutive lessons, where the lesson last 40 minutes. Every lesson delivered included a warm up activity, and for the intervention direct teaching was done employing the use of manipulatives, along with guided practice activities, and student reflection. Additionally, the teacher prompts the students and used guided questions which were documented during lessons to ensure consistency. So, as she used manipulatives, she assessed which seemed helpful or not, particularly based on instructional processes, and made changes to either the tool or how it is employed, as she leveraged real-time feedback from students. Furthermore, fidelity checks were made by both the cooperating teacher and my practicum supervisor to ensure there was alignment of the manipulatives with the lesson objectives, as well as the accessibility for all students and given them enough time to use them. Additionally, students kept journals and the teacher-researcher made observational field notes to facilitate record of the mid-cycle amendments. So, where it was necessary to simplify the use of manipulatives or consider the use of pictorial representations based on the physical representations to better connections, to avoid students being confused. The teacher-researcher was interested in finding out the challenges that affected students' conceptual understanding of algebra and geometry, allowing them to share their perspectives. These challenges included their own beliefs, experiences, and attitudes towards mathematics. Also, the teacher-researcher sought to use manipulatives to address these challenges while helping students really understand the concepts in Mathematics. The teacher-researcher engaging in this cycle of inquiry, implementation, reflection, and adjustment, hoped to measure the challenges and address them by creating meaningful improvement strategies that can be measured based on students' learning outcomes.

3.2 The Participants

The research was conducted at an all-boys high school with Grades 7 to 13. The research site is located in the Corporate Area of Jamaica. The population that was chosen had been were the last cohort from the Primary Exit Profile (PEP) Exams placement. The School itself had done a Grade 7 Diagnostic Test and the number of students that performed at the beginning and development level in Mathematics was approximately half for Mathematics in the PEP Exams in 2024 over an 8-week period. The Population for this experiment was approximately 320 grade 7 students. The reason this population was selected was because of the inconsistent and poor performance in Mathematics having recently done PEP Examinations. The original intended sample size was 15 students drawn from one Grade 7 class; however, the final sample was 11 because several students missed classes and/or either the pretest or the post-test. The sampling technique used was purposive sampling. John Dudovskiy [33] states that in the purposive sampling technique "the researcher relies on his or her own judgment when choosing members of population to participate in the study, .and often believe that they can obtain a representative sample by using a sound judgment". The limitation of this sampling technique was that you cannot generalize the findings to another population: such as another grade 7 in another school. Regardless the findings were applicable to this institution since the sample was a representation of this population.

3.3 Data Collection and Data Analysis

The teacher researcher utilized the following instruments in carrying out this research: Pre-Test, Post Test, Observations by the teacher, Student Questionnaire. The Initial Instrumentation used was a Pre-Test to assess the knowledge of the participants of the study before the teaching. Brophy [34] states that one advantage of using the Pretest and Post Test is that "Student learning can be inferred from the difference in student performance between two points in time". The Pre Test is a diagnostic test/assessment while the Post Test is a summative test/assessment. The Pre and Post Test were identical test issued at the beginning and again at the end of the six weeks to assess the changes in mathematical performance. This consisted of 10 geometrical questions. Questions 1 – 9 were multiple choice questions. Question 10 consisted of 6 completion questions in the format of fill-in-the-blank. The Pretest was done at the first class, while the post-test was done at week 6. The second data collection instrument that was used was Teacher Observations. These observations were field notes recorded by the teacher based on the observations of the levels of engagement, apparent understanding of the concept/topic taught, attitudes, and comments of the participants that the teacher believed would assist in determining the challenges students faced with mathematical performance. Observation in action research is a systematic way of collecting data by the researcher using all their senses to watch what the participants are doing primarily in a natural [35]. This method of data collection was necessary to collect primary data of this sample. This was to ascertain the behaviour, attitudes to learning, levels of frustration and the interaction which impacted the sample mathematical performance. The type of observation that was done was overt where the identity of the teacher-researcher and participants were revealed to each other and permission was sought. One limitation of using observation can be the Hawthorne Effect which Cherry [36] refers to it as the tendency of participants to work harder and perform better in a study because of their awareness of being observed. Other limitations include bias of the observer and time-consuming nature of action research to teach, observe and intervene using varying instruments. The third instrument used in the study was a student questionnaire, which can be defined as a structured data collection instrument that enables the systematic gathering of responses to specific questions [36]. According to Kuphanga [36], questionnaires are versatile and powerful tools for data collection, offering a standardized format that enhances the organization, analysis, and interpretation of data. He also highlights their cost-effectiveness, ease of administration, and ability to capture comprehensive insights from participants. This tool consisted of eight questions, primarily closed-ended, with the option for free-text responses to allow participants to elaborate if the predefined choices did not accurately reflect their views. The objectives for each question were as follows:

- Question 1: To ascertain which Math topics students found most challenging.
- Question 2: To ascertain students' emotions when faced with a Math Problem.
- Question 3: To ascertain students' belief on their reason for struggling in Maths.
- Question 4: To ascertain what students believe would assist them to improve in Mathematical performance.
- Question 5-8: To ascertain how the students felt about using manipulatives in class and if it they believed it helped to improve their performance.

This instrument was selected for its practical advantages as outlined by Kuphanga [36] and more importantly, to obtain firsthand feedback from students regarding their experiences before and after the intervention. The questionnaire aimed to verify whether the challenges affecting student performance, as perceived by the teacher-researcher, aligned with the students' perspectives. Additionally, it sought to capture students' reflections on how the use of manipulatives influenced their understanding and performance in mathematics. Despite its strengths, the questionnaire has some limitations, including the potential for misinterpretation of questions and the possibility that participants may not provide fully honest or reflective responses. The teacher-researcher ensured validity and reliability of the study by expert review of instruments to be used, member checking and the use of triangulation, two of the teacher-researcher's peers were asked to review the Pre-Test & Post-Test Questions and the Questionnaire study to ensure the validity of the study. When each item was reviewed, the experts checked for clarity to ensure the respondents can readily comprehend the intent especially considering age appropriateness, ensuring alignment with the research questions, and checking for content relevance. When they reviewed redundant questions were removed

Paper ID: SR25726084725 DOI: https://dx.doi.org/10.21275/SR25726084725

while others were reworded for greater clarity. The experts ensured that the questionnaire sought to produce results to answer the research questions. For instance, items such as "Do you believe using manipulatives help you understand geometric concepts in your mathematics classes?" and "Would you prefer using manipulatives in your mathematics classes?" that directly align to the research questions were considered for this investigation. After the collection of the data the stakeholders were presented with the findings of the study before it was shared with external parties to ensure that agree that the results is a true representation of their feelings. Furthermore, when the member-checking was done the participants had the opportunity to review summaries of their responses and how they were interpreted. Following, this only a slight amendment of a participant response was made to facilitate an update of the analysis, which was nothing major. This took the place of the field notes provided and the results of the questionnaire and the pre-test & post-test. This is called member checking, which lends to the validity of the study. The study used three methods of data collection known as triangulation which supported the reliability, since multi-perspectives were captured minimizing the risk of single-source bias. Data collected from the three different methods best supports a more accurate representation of the findings. Utilizing of the Observation Tool and Questionnaire gave a comprehensive view on the challenges with students' mathematical performance while the Questionnaire and the Post-Test reported on the effectiveness of the implemented intervention strategy to improve mathematical performance. The data collected in this study were analysed using a combination of quantitative and qualitative methods to ensure a comprehensive evaluation of the intervention's effectiveness. The qualitative data obtained from the student questionnaire and teacher observations were analysed using thematic analysis and confidence intervals. This approach enabled the teacher-researcher to identify recurring patterns and themes, allowing for the classification and organization of qualitative data into meaningful categories for interpretation and presentation. The study used inferential tests to complement the exploratory statistical inference with a small sample size ($n = 11$), instead of confirmatory. Quantitative data from the pre-test and post-test were analysed using comparisons of paired t-tests to assess statistically significant differences in student performance before and after the intervention. The Cohen's d and test statistics, effect sizes were used from the paired t-test in an attempt fortify transparency through the data and better reflect the limitations associated with the small sample zise. In addition, chi-square tests were initially conducted to examine relationships between categorical variables, particularly those related to students' perceptions captured in the questionnaire. However, due to the small sample size, key assumptions associated were violated since some expected cell frequencies were below 5. Thus, the study used Fisher's Exact Test. Wilson score confidence intervals were also used to estimate the precision of observed effects. The results of the paired t-test and chi-square analysis were presented in tabular form to clearly illustrate the impact of using manipulatives on student achievement. This mixed-methods approach allowed the researcher to draw well-supported conclusions based on both statistical evidence and participant feedback. Additionally, permission letters and consent forms were prepared and sent to the parents following the school's approval, which was secured by the second week of data collection. The data presented did not reveal the identity of the institution, the class or the individual participants at any time by the researcher. In the study, the name of the school was changed and pseudonyms were given to participants in order to protect their identity.

4. Results

4.1 Results Based on Research Question 1

What key challenges do Grade 7 male students in Jamaica face when learning algebraic and geometric concepts in mathematics?

This research question provides an analysis of several interconnected challenges Grade 7 students experienced while learning algebra and geometry. The study revealed that absenteeism, lack of understanding foundational concepts, and comprehending algebra and geometry were core challenges that these students encountered. The findings underscored that students who are absent from school are very likely to lose out on key lessons and fall behind. Also, students who lack an understanding of foundational concepts, especially those needed to progress in comprehending algebra and geometric concepts delivered at the Grade 7 level.

Absenteeism

Table 1 shows the attendance of each participant of the study over 6 consecutive school teaching lessons, mainly focusing on geometric topics, specifically shapes and solids. The teacher noticed that students were not present at all classes as presented in Table 1 from her attendance register. Table 1 showed only 2 of the 11 students were present for every lesson, who were Student D and Student F, while 9 out of 11 was absent for one or more lessons. Of the 9 students who were absent 44% (Students A, B, G, H, and K) were absent for two or more lessons. Chronic Absenteeism was also observed before the study in the general population. When the teacher researcher investigated the reason for absence, she received that either the students were not feeling well or the students were going to represent the school at an event. However, although these reasons are valid, the impact was evidence since students missed important concepts taught. For instance, Lessons 4 and 5 which covered the topics "Building Nets of Solids" and "Constructing Solids from the Nets and Classify Solids" were missed by Student B. This student lost the opportunity to understand 3D visualization, and spatial reasoning, which is core areas of geometry. Similarly, Student G missed 50% of these lessons, which provided key sessions, particularly through interactive learning strategies, including the "Mystery Solids Game", which was used to help student improve their conceptual understanding by engaging with discovery-based activities. The absence of the students from these scaffolding opportunities, gravely affected their learning process, causing a break even though the teacher attempted to minimize the missing of content by trying to quickly teach those participants the missing concept. Even with this attempt, the students are at a disadvantage in comparison to their peers, due to time constraints and face paced delivery of

Table 1: Sample of students' attendance and lesson topics associated

	Student	Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6
Topic		Types of Shapes	Exploring Real-World Solids	Solids – Mystery Solids Game	Building Nets of Solids	Construct Solids from the Nets and Classify Solids	Recap Solids and Nets of Solids
	A	1	1	0	1	0	1
	B	1	1	1	0	0	1
	C	1	1	1	0	1	1
	D	1	1	1	1	1	1
	E	1	1	1	0	1	1
	F	1	1	1	1	1	1
	G	1	0	0	1	0	1
	H	1	1	1	1	0	1
	I	1	1	1	0	1	1
	J	1	0	1	1	1	1
	K	1	1	1	0	0	1

Key to Interpret: 1 = present, 0 =absent

the content, lacking the depth as when first taught. The reality is that absenteeism often led to students missing out on the prerequisite knowledge needed. Students who missed foundational lessons such as "Types of Shapes" and "Exploring Real-World Solids", struggled to comprehend nets and classifying solids. Consequently, students had gaps in their procedural knowledge and lacked the conceptual connections to make sense across the geometry strand. Absenteeism appears to be one of the challenges affecting effective teaching and learning, and contributed to students' inability to comprehend geometric concepts and affect their overall mathematical performance.

Lack of Understanding

Figure 1 presents the responses of Grade 7 students regarding the perceived reasons for their struggles in mathematics, based on the questionnaire data. The majority of students, 8 out of 11 (73%), identified a lack of understanding as the main challenge. Additionally, 1 student (9%) attributed their struggle to poor teaching, while another student (9%) cited a lack of prior knowledge. One respondent selected the "Other" option, but did not specify a reason. These findings suggest that most students recognize gaps in their understanding rather than placing blame primarily on external factors, reinforcing the importance of using instructional strategies, such as concrete-representational-abstract, that support the use of manipulatives, supporting conceptual learning in a deep and

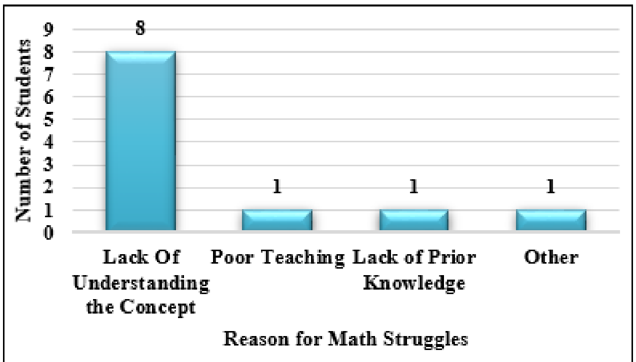

Figure 1: Students' reasons for their struggles with mathematics

more engaging method of learning Mathematics. Mangarin & Caballes [38] in their study reviewed and analysed existing studies to identify some of the difficulties encountered by students in learning mathematics. Their study suggest that a lack of conceptual understanding is a barrier in students' mathematical learning. They found that students often memorize procedures with proper conceptual understanding, limiting their ability to apply the knowledge to new problems and to engage in higher-order thinking [38, 39, 40].

Algebra and Geometry Challenges

Figure 2 illustrates the mathematics strands and skills that Grade 7 students in a Jamaican classroom found most challenging. The data revealed that 55% of students identified Algebra as the most difficult area, while 45% reported challenges with Geometry. These results indicate that Algebra and Geometry are the two most problematic domains for students at this level. The students found algebra challenging in terms of the algebraic rules they needed to follow, especially in manipulating expressions by making sense of the unknown values. This indicates that students who lack these skills tend to not engage in higher-order thinking and symbolic reasoning, expressing a sense of confusion, especially in making the transition from arithmetic to algebraic thinking in solving equations. On the other hand, students had challenges with spatial reasoning, including being able to visual the shapes, understand and apply the properties of solids, especially to construct or deconstruct nets related. As previously mentioned, part of the factor that affects students comprehending geometric concepts is attributed to their absence from lessons, including "Exploring Real-World Solids and "Constructing Solids from Nets". Many of them also expressed that due to the abstractness of the geometric properties, they found it hard to relate these properties to tangible shapes. This has made it difficult for them to classify different figures, as well as analyse them. Furthermore, progressing in learning future geometric concepts becomes problematic due to students' lack of the foundational concepts needed due to the cumulative nature of mathematics, which can create a cycle of struggling learners. However, this study focused specifically on improving mathematical performance, aligning with the intervention content delivered during the research. Thus, the teacher-researcher developed an intervention plan with the aim of addressing the areas students were found to be weak in, using manipulatives with the intent of reducing abstraction, engage students in hands-on activities, and enhance students' conceptual understanding. Additionally, besides enhancing performance, the intervention plan sought to bridge the gap that exist between the theory and the application using targeted strategies, particularly where students needed it most.

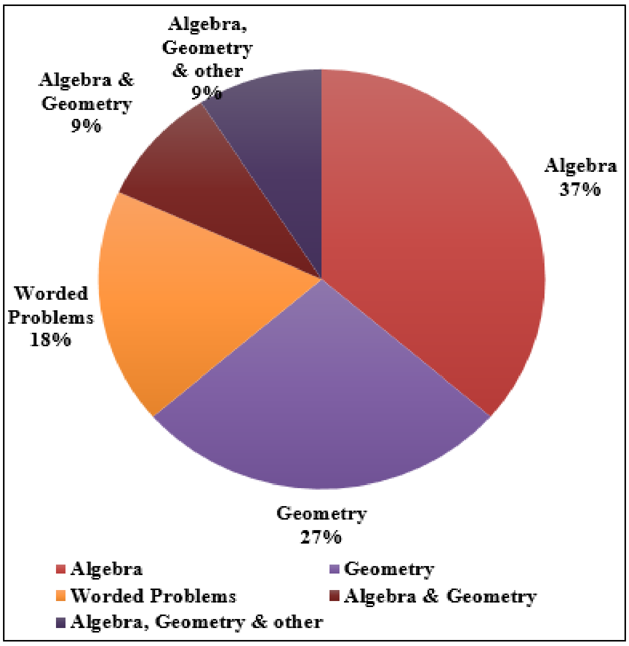

Figure 2: Mathematics topics students found most challenging

Figure 3 presents students' perspectives on the strategies they believe would improve their mathematical performance. The majority of students, 7 out of 11 (64%), expressed that the use of different teaching methods would be beneficial. Additionally, 3 out of 11 students, representing 27% believed that extra practice or supplementary lessons would support their understanding, while only one student (9%) highlighted the need for additional learning resources. These findings underscore the importance of instructional variety and active learning strategies, reinforcing the rationale for implementing manipulatives to enhance conceptual understanding and engagement in mathematics. Furthermore, the teacher-researcher observed challenges related to knowledge retention. Students often struggled to recall previously taught content. This issue was evident during the pretest, where students were assessed on topics that were taught at the primary level;

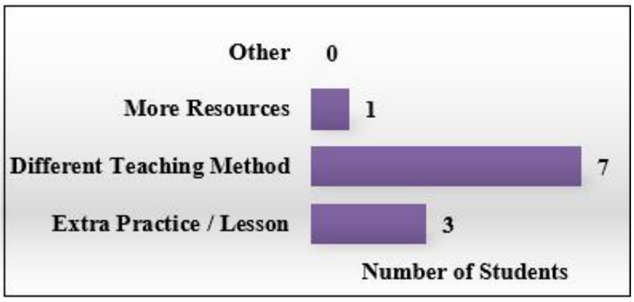

Figure 3: Students' perceptions of methods used to improve their mathematics performance nonetheless, 45% of the class failed the pretest. The implementation of manipulatives aimed to address these gaps by promoting deeper learning and long-term retention through hands-on, experiential instruction.

4.2 Results Based on Research Question 2

To what extent does the use of manipulatives enhance Grade 7 students' conceptual understanding and problem-solving abilities in algebra and geometry?

This section presents an analysis of the data collected to evaluate the effectiveness of using manipulatives as an instructional strategy to improve mathematical performance. The focus of the intervention was on the teaching and learning of geometric concepts, particularly three-dimensional solids and their corresponding nets—an area previously identified as challenging for students. During the intervention, a range of hands-on, tactile manipulatives were utilized to support student learning. These included real-life solid objects such as boxes and containers, a wooden 3D solid set, and paper nets that students cut, folded, and assembled to visually and physically explore the connection between two-dimensional and three-dimensional figures. These tools were used to help bridge the gap between abstract symbols and concrete understanding. This approach was grounded in Jerome Bruner's theory of the three modes of representation—enactive (physical manipulation), iconic (visual representation), and symbolic (mathematical notation)—as well as Piaget's theory of cognitive development, which emphasizes the importance of concrete experiences for learners at the concrete operational stage. Teacher observation notes documented a noticeable increase in student engagement, curiosity, and willingness to participate. Students expressed excitement, particularly during the "Guess What Solid is in the Box" activity, where they used their sense of touch and shape recognition to identify hidden solids. The student questionnaire responses gathered at the end of the intervention confirmed the positive reception of manipulatives.

Figure 4 illustrates the responses from the student questionnaire (Question 5) where 80% of students reported that they enjoyed using manipulatives during mathematics lessons, while 20% indicated they did not. This reflects a generally positive perception of the use of hands-on learning tools as an instructional strategy. The teacher-researcher also observed increased levels of engagement when students were provided with manipulatives, particularly during a structured

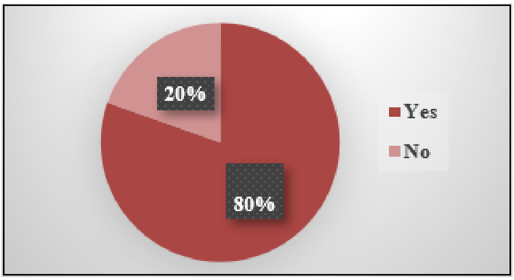

Figure 4: Students' perceptions of enjoying mathematics

activity called "Guess What Solid is in the Box." In this game-based task, students placed their hands inside a concealed box to feel a geometric solid, then identified the shape by counting its vertices, edges, and faces. Additionally, when students were tasked with assembling pre-cut nets to form three-dimensional solids, full class participation was observed, suggesting that manipulatives not only supported conceptual understanding but also encouraged active involvement and collaboration.

Table 2 shows that all 11 students would prefer to use the manipulatives either sometimes or all the time in class, according to the survey; however, one student reported that they didn't believe that it can help to improve their mathematical performance**.** This implies that there is a generally positive effect of using manipulatives for Grade 7 students' comprehension of algebraic and geometric concepts, coupled with their ability to solve problems. Furthermore, 9 students expressed (4 "Sometimes" and 5 "Definitely") that their use of manipulatives during lessons has helped them understand concepts better. Contrastingly, 2 students stated that using manipulatives, though enjoyable for lessons, did not affect them gaining understanding of algebraic and geometric concepts.

Table 2: Students' perceived impact of using manipulatives

Question	Definitely	Sometimes	Does not Matter	No	Total
6) Would you prefer to use manipulatives in your Math Classes?	4	7	0	0	11
7) Do you believe the use of manipulatives can help to improve your math grades?	3	7	0	1	11
8) Did you find that using manipulatives helped you to understand the concepts better?	5	4	0	2	11

Nonetheless, this minority response does not affect the majority view that manipulatives facilitate instructional supports that enhance the teaching and learning process. The results emphasized that hands-on learning resources, when incorporated as part of the teaching practices, provide students have the opportunity to deepen their mathematical understanding and improve their confidence in solving problems, especially in the challenging areas of algebra and geometry.

Table 3 below provides a summary of the comparison between the Chi-square test and Fisher's exact test. Initially, the Chi-square was considered but the sample size is too small to satisfy the key assumptions. The Fisher's test revealed that while the use of manipulatives had an overwhelming positive impact on students, the p-values vary for each indicated items on the questionnaire Q6, Q7 and Q8 precisely. For item Q6, the p-value of 0.083 > 0.05 indicated no statistical significance for students' preference to use manipulatives. However, it was found that a marginal trend exists since 11 students responded that they had a high inclination to use manipulatives "Definitely" or "Sometimes". On the other hand, Q7 and Q8 were revealed to be statistically significant with p-values 0.0003 and 0.0089 respectively, indicating students perceived that the use of manipulatives helped improve their grades and conceptual understanding of geometric concepts. Moreover, based on the Fisher's test, it is revealed that the low p-value indicates students' responses are not likely due to chance.

Table 3: Statistical summary and justification to use Fisher's exact test instead of Chi-square

Question	Observed Frequencies	Expected Counts (if equally distributed)	Statistical Test Used	Assumption Check	Adjustment Fisher's Exact Test (p-value)
Q6: Preference to use manipulatives	4 (Definitely), 7 (Sometimes), 0, 0	2.75 per category	Chi-square Goodness of Fit	Some expected < 5	0.083
Q7: Belief it improves grades	3, 7, 0, 1	2.75 per category	Chi-square Goodness of Fit	Some expected < 5	0.0003
Q8: Understanding improved	5, 4, 0, 2	2.75 per category	Chi-square Goodness of Fit + CI	Some expected < 5	0.0089

Table 4 shows that the Wilson score confidence intervals (CIs) provide insights into students' level of agreement in relation to items Q6, Q7, and Q8 which focused on students' perceptions of using manipulatives for mathematics instruction. The findings revealed for Q6 the 95% confidence interval range of 36.4% - 81.6%, which combined all students stated preference. This range indicate majority of the students hold a positive view, further reiterating findings for Table 2 and 3. On the other hand, for item Q7, the CI is 27.2% - 77.9% revealing that while some students believed the use of manipulatives helped to enhance their grades, the lower part of the range suggests less certainty of students' perceived improvement of grades. Contrasting, for Q8 the CI seen in Table 4 shows more consistency amongst students' agreement that the use of manipulatives, indeed, helped them understand geometric concepts. In essence, while students may not see the use of manipulatives for grade improvement, they can attest it being effective in comprehending geometric concepts taught. This suggests the need for a more targeted approach to address both performance and conceptual understanding.

Table 4: Proportion estimates and 95% confidence intervals (CI) for Questions 6-8 Students' responses

Question	Confidence Interval (95%)
Q6: Preference to use manipulatives	36.4% – 81.6% (combined preference)
Q7: Belief it improves grades	27.2% – 77.9% (combined "Yes")
Q8: Understanding improved	45.3% – 87.2% (answered "Definitely/Sometimes")

Figure 5 presents the students' test results before and after the intervention strategy - use of manipulatives to improve students' mathematics performance. The Pre-test and Post-Test were conducted under exam conditions with 11 students. Figure 5 shows the results of the pretest and post-test. The pre-test results showed that 6 of 11 students achieved grades of over 50% or higher in the pre-test, representing over 55% of students. The post-test results showed that 50% of these students did not improve after the intervention strategy, 33% improved, while 17% actually performed worse on the post-test. Five of eleven who failed the pretest but showed improvement on the post-test results. Student F showed remarkable improvement, moving from a grade of 20% to 80%. Student I also scored 20% on the pretest and managed to improve his score 100% to a grade of 40%. Interestingly, Figure 6 reveals that 3 out of the 11 students (A, C, and K) showed no improvement in mathematical performance after the intervention strategy. The three students scored between 93%, 60 and 80% respectively. Ten of the eleven students expressed that they believed the use of manipulatives would improve their mathematical performance sometimes or all the time while one student did not believe. Nine of out eleven students found that the use of the manipulatives helped. Teacher Observer noted that the use of manipulatives revealed improvements in students' mathematical performance after the use of manipulatives. From Figure 5 the arithmetic average for both pretest and the post test was calculated. The Pretest average = 56.91% The Post Test average = 72.09%. The difference in averages shows that the Post-Test average is 15% more than the pretest average, indicating a 15-percentage point gain on average. To get a deeper insight, a paired t-test was conducted on the pretest and post test scores using the following Hypotheses:

- H_0 (Null Hypothesis): There is no difference in the mean scores between the pretest and post-test. Any observed difference is due to chance.
- H_1 (Alternative Hypothesis): There is a significant difference in the mean scores between the pretest and post-test.

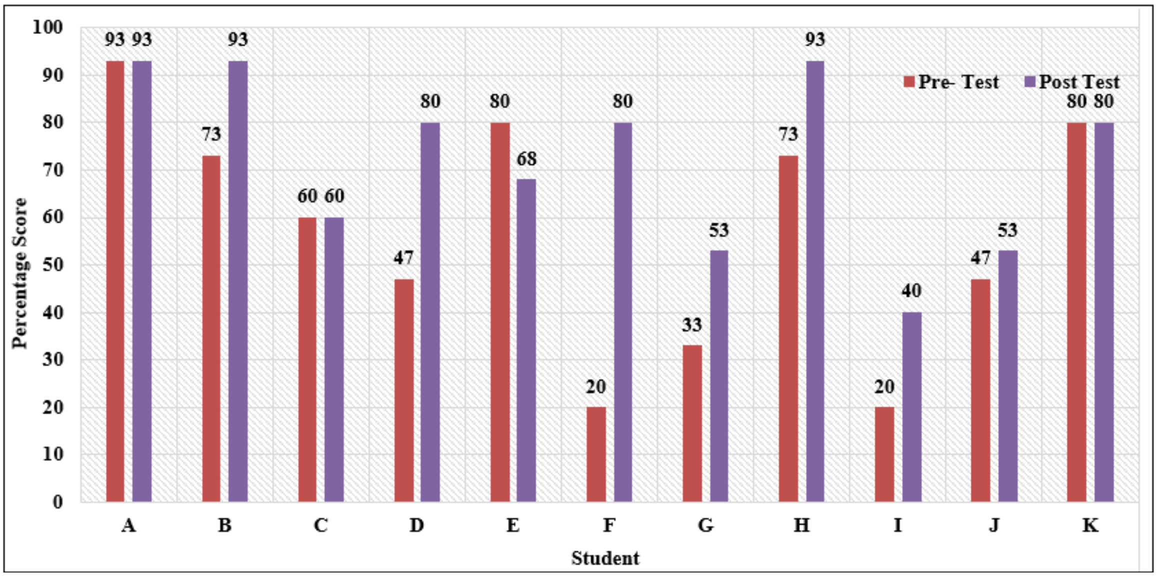

Figure 5: Students' test scores before and after mathematics intervention

The t-test revealed the test statistic (t = 2.54) and a p-value of 0.0294, which is less than 0.05 indicating that the result is statistically significant (see Table 5). Thus, the null hypothesis was rejected, and we accept the alternative that there is a significant difference between students' pretest and post-test scores. Additionally, the effect size based on Cohen's d is 0.77 revealing a moderate to large effect of the use of manipulatives on students' achievement, indicating that this is unlikely due to chance. This reflects that the use of manipulatives positively impacted students' performance.

Table 5: Paired t-test results

Measure	Pre-Test Mean	Post-Test Mean	Mean Difference	t-Statistic (df = 10)	p-value	Effect Size (Cohen's d)
Test Scores	56.91%	72.09%	15.18%	t = 2.54	0.0294	d = 0.77

Moreover, Figure 6 supported the t-test results showing that 64% of the participating students experienced improvement in their mathematical performance compared to 27% who showed no improvement, while 9% expressed that they experienced a decline in their mathematical performance with the use of this strategy. This highlights that while the use of manipulatives is beneficial to most of the students, not all learners are equally supported, indicating that a more intentional approach of differentiated instruction is warranted.

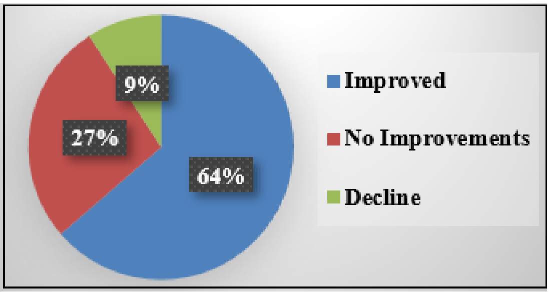

Figure 6: Students' perceived mathematics improvement after intervention

Paper ID: SR25726084725 DOI: https://dx.doi.org/10.21275/SR25726084725

4.3 Further Discussions and Implications

The findings of this study highlighted several key challenges impacting students' mathematical performance of Grade 7 students. A key issue identified was absenteeism and the study by Covelli & Steiner [41] noted that the connection between chronic absenteeism and declines in math is not coincidental. They also reported that the American Educator Study found that more than 30% of principals stated that chronic absenteeism was a major obstacle for math learning and the students most at risk were from lower economic communities. Chronic absenteeism is considered to be as a result of students missing more than 10% of class attendance which can vary from one institution to the next [41]. The data in Table 1 shows a chronic absenteeism level of 36%, revealing that students' learning have been disrupted, where they failed to achieve some mathematics learning objectives, and eventually others even when they are present based on the spiral and cumulative nature of the mathematics curriculum. Missing critical lessons can hinder the student's ability to grasp more complex concepts hence leading to poor performance. There is a need to investigate the reasons students are absent and what support can be put in place to ensure that students attend classes or make-up classes are given whether face to face or virtually. Another challenge that was identified was the lack of understanding. Figure 1 revealed that 73% of students blamed a lack of understanding as their main challenge with math performance. Many studies support this as a leading challenge to students' mathematical performance. Collins *et al* [1] study that focused on Grades 8 & Grade 9 in Jamaica, revealed that 75% of students lacked understanding in various mathematical concepts, further supporting the need to use intervention strategies such as the use of manipulatives.

This study revealed that 67% of students would like to see different teaching methods implemented in the classroom to help them understand math concepts better, leading to better in performance in Mathematics (see Figure 3) therefore utilizing a variety of teaching strategies is essential in meeting the learning styles of students to improve learning outcomes. The main mathematics topics from this study that students believed were the most challenging were algebra and geometry. Data in Table 1 showed that up to 55% of students found Algebra challenging and up to 45% of students found Geometry challenging. Algebra involves abstract thinking while Geometry requires strong spatial reasoning and visualization. Since there is an issue with these topics in Mathematics a strategic standard approach using best practices should be employed when teaching these topics. One observation that the teacher-researcher made was that there seems to be a retention issue when it came to teach mathematics and that can account for low prior knowledge or prerequisite knowledge that contributes to poor performance.

The findings of this study revealed that manipulatives is a useful tool in improving mathematical performance as seen in Figure 6. In a study by Hurst and Linsell [26] as cited by Lange [42] found that students' mathematical performance and conceptual understanding improved with the use of manipulatives. The overall average of the students' performance improved with the use of manipulatives. Students who failed the pretest benefitted the most from the use of the manipulatives after 20% and 73% showed improvement

However, in this study the manipulatives were not effective for students who were already performing well - and the implementation of manipulatives for these students resulted in either no improvement or a decline in mathematical performances as illustrated in Figure 5 where 9% of the students saw a decline in performance. The decline was for student E who performed well receiving a grade of 80% on the pretest but then only managed to score 68% on the post test. He was only absent for one day though so there may be other factors that contributed to his decline in performance.

Here are some implications to consider based on the findings:

- The need to address chronic absenteeism which has impacted students' mathematics performance. School administrators can consider root causal analysis, flexible learning options and stronger parental engagement strategies.
- The growing need for differentiated instruction in the mathematics classroom to become a standard practice since the one-size-fits-all approach does not work based on the findings, 67% of the students requested varying the teaching methods.
- Educators should consider developing specialized pedagogical approaches to teach algebra and geometric concepts using targeted teaching frameworks.

Manipulatives based on the findings were good for low performing students; however, there needs to modification of teaching methods to facilitate advanced learners.

5. Conclusion

This action research showed that manipulatives can meaningfully improve geometry performance and engagement among Grade 7 students in a Jamaican secondary school, with 64 percent of learners improving and a statistically significant gain in mean post-test scores. However, the benefits were not universal; higher-performing students did not always gain, and a minority declined, underscoring the need for differentiated pathways and careful alignment between manipulative choice and learner readiness. Chronic absenteeism and weak conceptual foundations remain structural obstacles to sustained growth. Future studies should adopt larger, multi-site samples with control groups, report effect sizes and assumption checks, and examine how manipulative-based instruction interacts with technology, discovery learning, and teacher professional development to support both low and high-achieving students.

6. Recommendations

Based on the findings the following recommendations can be utilized for future research and improve pedagogy:

1) The need to properly explore the effectiveness on the use of manipulatives to improve mathematical performance for grade 7 students using two experimental groups and two control groups at two different high schools. This may help to better see how the students respond to the stimuli, to know the real benefits of manipulatives if any.
2) A careful examination of the effectiveness of the use of manipulatives across algebra and geometry topics to improve conceptual understanding in a grade 7 classroom in Jamaica. This is especially suggested since the limitation of the Pre Test and Post Test were discovered to be students' familiarity to the Tests questions which may be the actual reason for improvement and not the intervention strategy.
3) Teacher researcher should continue to use manipulatives into daily mathematics lessons while catering to other teaching styles for the differentiated classroom.
4) Teacher researcher should get professional development for the use of both physical and virtual manipulatives to ensure the correct selection and use of manipulatives in all lessons.

Acknowledgements

The authors would like to extend their gratitude to all those individuals who have supported the completion of this research. We wish to thank the Shortwood Community including colleagues for their expertise in guiding me with specific mention of the following persons: the head of the mathematics department, practicum supervisor and research supervisor. Also, a heartfelt gratitude to faculty members, participants and parents of the high school where I did my research for allowing me to conduct this research at their institution and/or for their permission/ participation in this research. This research would not have been possible with the combined support of all the individuals mentioned above.

References

[1] Collins, A. et al. (2023 July 11). *Understanding and Problem-Solving Skills in the Jamaican Mathematics Classroom "A Cross-Sectional Study Investigating the Effects of Learning-Based Activities, Algebra Tiles and Problem-Solving Teaching Techniques on Students' Conceptual Understanding and Problem-Solving Skills* American Journal of Educational Research. 11. 440-456. https://doi.org/10.12691/education-11-7-1.

[2] Williams, A. (2023, June 24). *Pep In Step Jamaica Gleaner.* Retrieved from https://jamaica-gleaner.com/article/lead-stories/20230624/pep-step.

[3] Organisation for Economic Co-operation and Development (OECD). (2024). Mathematics Performance (PISA) Retrieved February 2, 2025 from https://data.oecd.org/pisa/mathematics-performance-pisa.htm?context=OECD.

[4] Loop News. (2024, August 30). *Jamaica 'Cannot Develop Without Us Doing Better At Math' – Holness.* Loop News. *https://www.loopnews.com/content/jamaica-cannot-develop-without-us-doing-better-at-math-holness/.*

[5] World Economic Forum (2020) Future of Job Report 2020. https://www.weforum.org/reports/the-future-of-jobs-report-2020/in-full/infographics-e4e69e4de7.

[6] Larbi, E. & Okeyere M. (2016) *The Use Of Manipulatives in Mathematics Education.* Journal of Education and Practice ISSN 2222-1735 (Paper) ISSN 2222-288X (Online) Vol.7, No.36, 2016 https://files.eric.ed.gov/fulltext/EJ1126428.pdf.

[7] Hussein, Y. F., & Csíkos, C. (2023). The effect of teaching conceptual knowledge on students' achievement, anxiety about, and attitude toward mathematics. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(2), em2226. https://doi.org/10.29333/ejmste/12938.

[8] Bruner, J. (2009) The Process of Education. A landmark in Educational Theory. Harvard University Press.

[9] Tozzo, B. 2017 December 29. *Jerome Bruner - A Singapore Maths Icon*. Dr. Bill Tozzo. https://www.billtozzo.com/jerome-bruner-a-singapore-mathematics-icon/.

[10] Currell, J. (2024). *Using Jerome Bruner's key theories in teaching practice.* Maths No Problem. https://mathsnoproblem.com/blog/teaching-tips/jerome-bruner-theories-put-into-practice.

[11] Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press https://home.fau.edu/musgrove/web/vygotsky1978.pdf

[12] Dong, A., Siu-Yung Jong, M. & King, R. (2020). *How Does Prior Knowledge Influence Learning Engagement? The Mediating Roles of Cognitive Load and Help-Seeking* Frontiers in Psychology. 2020 October 29 Sec. Educational Psychology https://doi.org/10.3389/fpsyg.2020.591203.

[13] Gafoor, K. A. and Kurukkan, A. 2015 *Learner and Teacher Perception on Difficulties in Learning and Teaching Mathematics: Some Implications* National Conference on Mathematics Teaching- Approaches and Challenges December 21 -22, 2015 https://files.eric.ed.gov/fulltext/ED568368.pdf.

[14] García, E., & Weiss, E. (2018). *Student absenteeism: Who misses school and how missing school matters for performance*. Economic Policy Institute. https://www.epi.org/publication/student-absenteeism-who-misses-school-and-how-missing-school-matters-for-performance/.

[15] Grant, S. (2025, July 17). *Reducing absenteeism is essential to achieving equity in education system – Minister*. Jamaica Information Service. https://jis.gov.jm/reducing-absenteeism-is-essential-to-achieving-equity-in-education-system-minister/.

[16] Williams, F. (2023, January 25). *MOEY: Committed To Providing Quality Education*. The Jamaica Observer https://www.jamaicaobserver.com/2023/01/25/moey-committed-to-providing-quality-education/.

[17] Richardson, F.C., and R.M. Suinn. "The Mathematics Anxiety Rating Scale: Psychometric Data." Journal of Counseling Psychology 19 {1972): 551-554.

[18] Ruff, S.E. & Boes, S. (2014) *The Sum of All Fears: The Effects of Math Anxiety on Math Achievement in Fifth Grade Students and the Implications for School*

Counsellors. November 2014 *https://files.eric.ed.gov/fulltext/EJ1084441.pdf*.

[19] Geddes, L. (2022, February 7) *Teachers And Too Much Homework Contribute To Maths Anxiety – Study* The Guardian 2022 https://www.theguardian.com/education/2022/feb/07/teachers-and-too-much-homework-contribute-to-maths-anxiety-study.

[20] YLE News. (2020, April 15). *Study: Bad marks in maths undermine kids' self esteem*. News. University of Jyväskylä. https://yle.fi/a/3-11305055.

[21] Pekrun, R., Lichtenfeld, S., Marsh, H., W., Murayama, K. and Goetz, T. (2017) Achievement emotions and academic performance: longitudinal models of reciprocal effects. Child Development, 88 (5). pp. 1653-1670. ISSN 0009-3920 doi: 10.1111/cdev.12704 Available at https://centaur.reading.ac.uk/65981/.

[22] Aguilar, J. J. (2021). High School Students' Reasons for disliking Mathematics: The Intersection Between Teacher's Role and Student's Emotions, Belief and Self-efficacy. International Electronic Journal of Mathematics Education, 16(3), em0658. https://doi.org/10.29333/iejme/11294.

[23] Searchlight. (2024, September 14). *Students not making it to University due to poor performance on maths and English - Searchlight*. Widget Area Template-20211011132950. https://www.searchlight.vc/front-page/2024/08/23/students-not-making-university-due-poor-performance-maths-english/.

[24] Hidayah, I. et. al. (2021). Quality Management of Mathematics Manipulative Products to Support Students' Higher Order Thinking Skills. International Journal of Instruction, 14(1), 537-554. https://doi.org/10.29333/iji.2021.14132a.

[25] Cockett & Kilgour (2015) *Mathematical manipulatives: Creating an environment for understanding, efficiency, engagement, and enjoyment* Teach Collection of Christian Education Volume 1 Issue 1 Article 5 https://research.avondale.edu.au/cgi/viewcontent.cgi?article=1004&context=teachcollection.

[26] Hurst, C. and Linsell, C. (2020 September 7). Manipulatives and Multiplicative Thinking. European Journal of STEM Education, 5 (51), 04. https://files.eric.ed.gov/fulltext/EJ1267965.pdf.

[27] Puchner, L., Taylor, A., O'Donnell, B., and Fick, K. (2010). Teacher learning and mathematics manipulatives: A collective case study about teacher use of manipulatives in elementary and middle school mathematics lessons. School Science and Mathematics, 108(7), 313-325. https://doi.org/10.1111/j.1949-8594.2008.tb17844.x.

[28] Ministry of Education, Youth & Information, Jamaica (2018). *National Standards Curriculum Guide Mathematics Grade 7 APSEI* Mathematics-FINAL.pdf (moey.gov.jm).

[29] Amiyani, R. and Widjajanti J. B. , 2018 The Excellence of Guided Discovery Learning on Mathematical Knowledge-Based, Skill-Based, and Attitude Journal of Physics: Conference Series, Volume 1097, The 5th International Conference on Research, Implementation, & Education of Mathematics and Sciences 7–8 May 2018, Yogyakarta, Indonesia 1097 012145 DOI 10.1088/1742-6596/1097/1/01214 Open Access proceedings Journal of Physics: Conference series (iop.org).

[30] Liburd, K. K., & Jen, H. (2021). Investigating the effectiveness of using a technological approach on students' achievement in mathematics–case study of a high school in a Caribbean country. *Sustainability*, *13*(10), 5586. https://doi.org/10.3390/su13105586.

[31] Parsons, R. D., & Brown, K. S. (2002). Teacher as reflective practitioner and action researcher. Belmont.

[32] NCTM (National Council of Teachers of Mathematics), 2024. *How is Action Research Defined*https://www.nctm.org/uploadedFiles/Grants_and_Awards/grants/How%20is%20Action%20Research%20Defined.pdf.

[33] Dudovskiy, J. (n.d.) *Purposive Sampling* Business Research Methodology. https://research-methodology.net/sampling-in-primary-data-collection/purposive-sampling/.

[34] Brophy, T. (n.d.) Module 5B - *Pre and Post Testing for Student Learning* chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://assessment.aa.ufl.edu/media/assessmentaaufledu/practical-guide-materials/Module-5b---Pre-and-Post-testing---PowerPoint.pdf.

[35] Crawford, R. (2022). *Action Research as Evidence-based Practice: Enhancing Explicit Teaching and Learning through Critical Reflection and Collegial Peer Observation*. Australian Journal of Teacher Education. 47(12). https://files.eric.ed.gov/fulltext/EJ1388397.pdf.

[36] Cherry, K. (2023 July 6) *How the Hawthorne Effect Works.* https://www.verywellmind.com/what-is-the-hawthorne-effect-2795234.

[37] Kuphanda, D. (2024 March 11) Questionnaires in Research: Their Role, Advantage and Main Aspects. https://www.researchgate.net/publication/378868278_Questionnaires_in_Research_Their_Role_Advantages_and_Main_Aspects#.

[38] Mangarin, C & Caballes, D. (2024 October 3) *Difficulties in Leaning Mathematics: A Systemic Review . International Journal or Research And Scientific Innovation* https://rsisinternational.org/journals/ijrsi/articles/difficulties-in-learning-mathematics-a-systematic-review/.

[39] Rittle-Johnson, B., & Schneider, M. (2015). Developing conceptual and procedural knowledge in mathematics. In R. Cohen Kadosh & A. Dowker (Eds.), Oxford handbook of numerical cognition (pp. 1102-1118). Oxford, UK: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199642342.013.014.

[40] Rittle-Johnson, B. Schneider, M. & Star, J. (2015). Not a one-way street: Bi-directional relations between procedural and conceptual knowledge of mathematics. Educational Psychology Review, 27. https://doi.org/10.1007/s10648-015-9302-x.

[41] Covelli, L. & Steiner, E. (2024 March 4) *Chronic Absenteeism and Math Learning Loss are Adding Up:* RAND https://www.rand.org/pubs/commentary/2024/02/chron

ic-absenteeism-and-math-learning-loss-are-adding.html.
[42] Lange, J (2021) *The Importance of Using Manipulatives in Math Class* [Master's Theses and Capstone Projects] NWCommons, Northwester College Iowa https://nwcommons.nwciowa.edu/cgi/viewcontent.cgi?article=1291&context=education_masters.