

UNIVERSITY OF EDUCATION, WINNEBA

**EFFECT OF TINKERCAD ON JUNIOR HIGH SCHOOL STUDENTS'
ACHIEVEMENT IN GEOMETRY: A STUDY OF TWO SCHOOLS IN ACCRA**



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ACHIEVEMENT IN GEOMETRY: A STUDY OF TWO SCHOOLS IN ACCRA**



**A Project Report in the Department of Educational Foundations,
School of Education and Life-Long Learning, submitted to the school of
Graduate Studies in partial fulfilment
of the requirements for the award of the degree of
Post Graduate Diploma
(Education)
in the University of Education, Winneba**

OCTOBER, 2025

DECLARATION

Student's Declaration

I, Olivia Asante, hereby declare that this project report content of this write up was solely done by me. It contains no material previously published by another person or material which have been accepted for the award of any other degree of the University, except where due acknowledgement has been made to the text.

Signature

Date

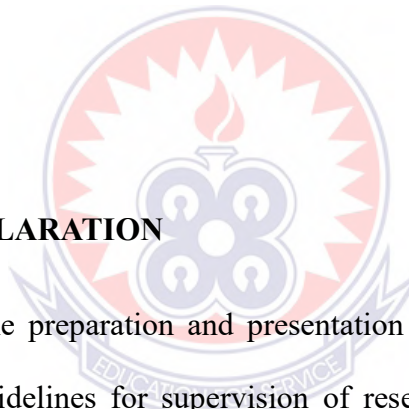
SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of research work as laid down by the University of Education, Winneba.

Name:

Signature.....

Date



DEDICATION

To my beloved father, Oliver Kofi Asante



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I wish to extend my sincere appreciation to my supervisor, Dr. Joseph Appianing, whose support, guidance, and unwavering encouragement greatly enriched this research and made the completion of this work possible.

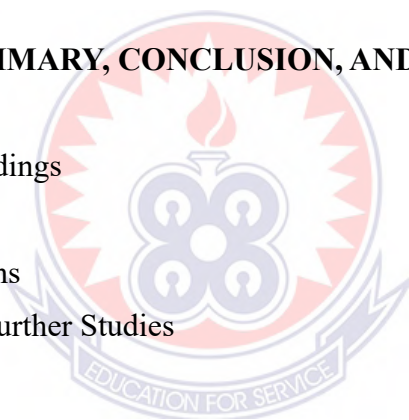
Finally, I would like to acknowledge my brother, Prince Obour Mintah, for his immense support and contribution toward the successful completion of this programme, as well as my entire family for their prayers, patience, and encouragement



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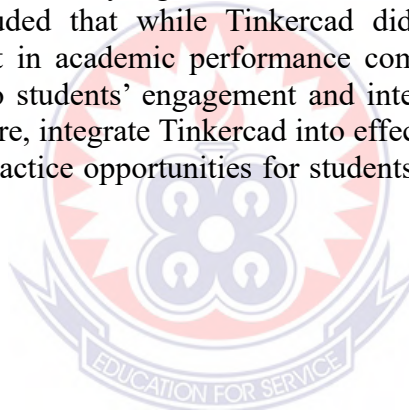


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ABSTRACT

This study investigated the impact of Tinkercad, a 3D modeling software, on the achievement of Junior High School students in geometry. The study was motivated by persistent poor performance in geometry among Ghanaian students, which has often been attributed to abstract approaches to teaching the subject and a lack of use of manipulative learning tools. A quasi-experimental pretest–posttest control group design was adopted. The sample comprised 80 students selected from two private Junior High Schools in Accra. Whereas the experimental group was taught some selected topics in geometry with the aid of Tinkercad, the control group received instruction using traditional methods. A geometry achievement test, developed by the researcher, was used to collect data at pre- and post-treatment points. Both descriptive and inferential statistics, including paired and independent samples t-tests, were used in the analysis. The results revealed that even though both groups showed an improvement in their performance at the post-test, only the improvement among students in the control group reached statistical significance. Also, the mean post-test scores of the control group were higher than those of the experimental group. There were no statistically significant differences in performance by gender. The study, therefore, concluded that while Tinkercad did not result in any statistically significant improvement in academic performance compared to traditional teaching, it contributed positively to students' engagement and interest in the lessons on geometry. Teachers should, therefore, integrate Tinkercad into effective instructional strategies, with adequate training and practice opportunities for students to maximize its full potential in mathematics education



CHAPTER ONE

INTRODUCTION

Geometry plays a crucial role in mathematics education, providing a foundation for logical reasoning, spatial understanding, and problem-solving. However, many Ghanaian Junior High School students continue to struggle with geometric concepts due to their abstract nature and the limited use of interactive instructional materials. Teachers often rely on traditional, teacher-centered approaches that make it difficult for learners to visualize and apply geometric principles effectively. This challenge contributes to students' low achievement in mathematics and a general lack of interest in geometry-related topics. Advancements in educational technology now provide opportunities to make abstract mathematical concepts more concrete and engaging. One such innovation is Tinkercad, a three-dimensional (3D) computer-aided design (CAD) tool that allows learners to construct and manipulate virtual geometric shapes. Through visualization and hands-on modeling, Tinkercad can help students develop spatial reasoning and better conceptual understanding. Despite its potential, the use of such technology remains uncommon in most Ghanaian classrooms, especially at the basic education level. This study therefore examined the effect of Tinkercad on Junior High School students' achievement in geometry in two selected schools in Accra. Specifically, the study sought to determine whether integrating Tinkercad into geometry instruction would lead to improved academic achievement compared to traditional teaching methods, and to

explore possible gender differences in performance. The findings are expected to contribute to effective technology integration in mathematics teaching and learning at the basic school level

1.1 Background to the Study

In the rapidly evolving landscape of science, technology, engineering, and mathematics (STEM) education, the integration of digital tools has become critical in fostering innovative teaching and enhancing students' cognitive development (Yang et al., 2024). Among these tools, Tinkercad, a web-based computer-aided design application developed by Autodesk which has gained considerable attention for its potential in enhancing spatial reasoning and geometry achievement, particularly at the junior high school level (Williams, 2022). Originally designed for prototyping and 3D modeling, Tinkercad provides an interactive, visual environment where students can construct, manipulate, and analyze geometric forms in a virtual 3D space. These capabilities align directly with the goals of geometry instruction, which seeks to develop students' understanding of shapes, spatial relationships, transformations, and measurement (Mulligan, 2015). Despite its importance, traditional classroom approaches to geometry instruction often rely heavily on rote memorization, two-dimensional representations, and limited opportunities for hands-on engagement. This creates a gap between abstract mathematical concepts and students' ability to internalize and apply them effectively. Geometry is a foundational component of mathematics education, essential for developing spatial reasoning, problem-solving skills, and logical thinking (Jones & Tzekaki, 2016). Globally, however, students often struggle with geometry, leading to suboptimal performance. For instance, the 2023 Trends in International Mathematics and Science Study (TIMSS) revealed that while 92% of

Japanese and 89% of Singaporean eighth-grade students achieved proficiency in mathematics, only 64% of Australian students reached this level, highlighting significant disparities in geometry comprehension worldwide (Sabbagh, 2023).

In Africa specifically, where comprehensive data remains limited, the UNESCO Institute for Statistics reported that less than 10% of children in Sub-Saharan Africa achieve minimum proficiency levels in mathematics by the end of lower secondary education. The introduction of digital technology tools into mathematics education presents promising opportunities to address these challenges. Tinkercad, a free online 3D design and modeling application, stands as one such tool with the potential to transform how students conceptualize and interact with geometric concepts (Barbosa, Vale, & Alvarenga, 2024). By enabling students to manipulate three-dimensional objects in a virtual environment, it may offer scaffolding for the development of spatial visualization abilities that traditional pedagogical approaches have struggled to provide. The application of educational technology, such as Tinkercad, introduces opportunities to bridge this gap. With its intuitive drag-and-drop interface and immersive 3D modeling environment, it supports experiential learning, promotes visualization, and encourages learners to engage with geometric concepts more meaningfully and interactively (Chen, Chen, & Shan, 2024). Studies also indicate that integrating Tinkercad into the curriculum can enhance students' computational thinking skills, creativity, and problem-solving abilities. By providing an interactive and engaging learning environment, Tinkercad has the potential to improve geometry comprehension among JHS students (Eryilmaz & Deniz, 2021). Moreover, it aligns with the principles of constructivist learning theory, which posits that students construct

knowledge more effectively when they actively participate in problem-solving and manipulation of real or virtual objects (Al Abri, Al Aamri, & Elhaj, 2024).

In Ghana and other developing countries, integrating digital tools in junior high school mathematics education is still emerging. However, with the government's increasing investment in ICT infrastructure and STEM initiatives, there is a growing opportunity to explore the impact of such tools on learners' outcomes. Despite Tinkercad's growing use in technical and vocational training, empirical research examining its pedagogical impact, especially on cognitive outcomes such as geometry performance at the junior high school level, remains limited.

1.2 Statement of the Problem

Despite the critical role that geometry plays in developing students' spatial reasoning, logical thinking, and problem-solving skills, performance in this area remains persistently low among Junior High School (JHS) students, both globally and in Ghana (Sam et al., 2024). Numerous studies, including the 2023 TIMSS report, indicate that students across many regions struggle to grasp fundamental geometric concepts, with African countries often recording below-average proficiency levels (Quarshie, 2023). In Ghana specifically, research conducted on the Van Hiele levels of geometric thinking revealed that a majority of JHS students remain at the most basic level of geometric understanding, visualization, suggesting minimal conceptual progression and a lack of higher-order reasoning skills in geometry (Quarshie, 2023). This poor performance has been attributed to several factors, including traditional instructional approaches that are overly theoretical, abstract, and disengaging for learners. With the increasing availability of digital learning tools, educational technologies like Tinkercad, a free, user-friendly online platform for 3D

design, offer new possibilities for transforming the way geometry is taught and understood (Turienzo, 2024). However, there is a significant research gap concerning the empirical evaluation of such tools within the Ghanaian JHS context (Yeboah, 2023). Specifically, it is unclear to what extent the integration of Tinkercad into the mathematics curriculum influences students' understanding and performance in geometry. There is also limited data on whether such tools can effectively address the challenges students face with spatial visualization and the application of geometric concepts in real-world contexts (Fokuo et al., 2023). Without research-based insights, educators may be reluctant or unequipped to incorporate such tools into their teaching practice. This study seeks to address this gap by assessing the effect of Tinkercad on Junior High School Students' Performance in Geometry.

1.3 Purpose of the Study

The purpose of this study was to examine the effect of Tinkercad on Junior High School (JHS) students' achievement in geometry in selected private schools in Accra. Specifically, the study sought to determine whether the use of Tinkercad in teaching selected geometry topics would lead to better academic performance compared to traditional instructional methods. The study also aimed to investigate possible gender differences in students' achievement when taught with Tinkercad.

1.4 Specific Objectives

This study was designed to:

1. assess the effectiveness of Tinkercad on students' academic achievement in geometry among selected private Junior High School (JHS) students in Accra.

2. compare the academic achievement of selected private JHS students in Accra who were taught geometry using Tinkercad with those taught using traditional instructional methods.
3. examine gender differences in the academic achievement of selected private JHS students in Accra when taught geometry using Tinkercad.

1.5 Research Hypotheses

The study was guided by the following null hypotheses:

1. H_{01} : There is no statistically significant effect of Tinkercad on students' academic achievement in geometry among selected private Junior High Schools (JHSs) in Accra.
2. H_{02} : There is no statistically significant difference in academic achievement between selected private JHS in Accra taught geometry using Tinkercad and those taught through traditional instructional methods.
3. H_{03} : There is no statistically significant gender difference in the academic achievement of selected private JHS students in Accra when taught geometry using Tinkercad.

1.6 Significance of the Study

This study is significant because it provides insight into how the integration of digital modeling tools such as Tinkercad can enhance the teaching and learning of geometry at the Junior High School level in Ghana. The findings will be valuable to mathematics teachers, school administrators, curriculum planners, and educational policymakers who seek innovative ways to improve students' understanding of abstract mathematical concepts.

For mathematics teachers, the study demonstrates the potential of Tinkercad as a practical tool for visualizing and manipulating geometric shapes, which can make geometry lessons more interactive and learner-centred. It will also guide teachers in adopting technology-based strategies that cater to diverse learning needs and abilities.

School administrators and heads of private Junior High Schools may use the results to justify the inclusion of educational technologies in classroom instruction and to provide the necessary logistical support and training for teachers.

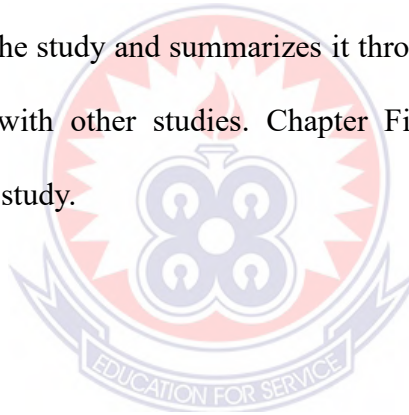
Additionally, the study contributes to the growing body of literature on technology integration in basic education in Ghana, particularly in mathematics education. The findings may inform curriculum developers and policymakers at the Ghana Education Service and the National Council for Curriculum and Assessment (NaCCA) on how digital tools can be effectively incorporated into instructional practice to promote better learning outcomes.

1.7 Delimitation of the Study

This study was delimited to two selected private Junior High Schools in Accra. The focus was on assessing the effect of Tinkercad, a three-dimensional (3D) modeling software, on students' academic achievement in geometry. Only Form Two students were involved in the study because they had already been introduced to basic geometric concepts in the mathematics curriculum. The study covered selected topics in plane and solid geometry and did not include other areas of mathematics such as algebra, statistics, or trigonometry. The research was limited to evaluating students' achievement and gender differences; it did not explore students' attitudes, motivation, or teachers' perceptions of Tinkercad.

1.8 Organization of the Study

The study is systematically organized into five chapters as follows: Chapter one constitutes the introductory chapter which consists of sections such as the background of the study, statement of the problem, the objectives of the study, the research questions, the significance of the study, delimitations of the study, and organization of chapters. Chapter Two reviews literature on the study objectives. Chapter three constitutes the methodology. The chapter outlines, in detail, the research design, the target population of the study, the sample size, the sampling procedures, the data collection instrument, and the statistical tools used in the data analysis. Chapter Four represents the results and findings. It presents the data collected from the study and summarizes it through a graphical presentation, and discusses the findings with other studies. Chapter Five presents the conclusion and recommendations of the study.



CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This literature review presents previous research relevant to the effect of Tinkercad on Junior High School students' achievement in geometry. It focuses on how technological tools enhance teaching and learning mathematics, especially geometry, at the basic education level. It examines theoretical perspectives that support the integration of technology, empirical studies related to using digital tools to facilitate mathematics instruction, and a conceptual framework that summarizes the major variables of the study. The purpose of the review is to establish a basis for this study by identifying gaps that were left by prior research and showing how the integration of Tinkercad, which is software for 3D modeling, influences students' understanding and achievement in geometry. The chapter proceeds with discussing the underpinning theoretical framework, followed by reviewing related empirical research and a conceptual framework that summarizes the relationships among the major study variables.

2.1 Theoretical Review

The study that investigates the effect of Tinkercad on junior high school students' achievement in geometry is based on several theoretical approaches that focus on how

digital tools enhance learning, especially in mathematics and spatial reasoning. These theories collectively provide a foundation for understanding how students interact with technological tools, construct knowledge, and translate visual information into conceptual understanding. The main theoretical foundations of this study rest on the Constructivist Learning Theory, Dual Coding Theory, Cognitive Load Theory, Multimedia Learning Theory, and the Technology Acceptance Model (TAM).

2.1.1 Constructivist Learning Theory

Constructivist learning theory, by Jean Piaget (1970) and later developed by Lev Vygotsky (1978), suggests that learning is an active process of knowledge construction rather than transmission. Learners are not passive recipients of information but rather active processors and interpreters of experience and new ideas within their schematic frameworks. Understanding in this approach emanates from an individual's interaction with people, materials, and concepts rather than through rote memorization or direct instruction.

This understanding is particularly deep in the context of mathematics and, more importantly, geometry. Geometry is a subject that relies on visualization, exploration, and reasoning about spatial relationships. It deals with creating mental representations of shapes, dimensions, and structures that are continually updated through hands-on activities and experimentation. Thus, constructivist geometry classrooms emphasize student-centered learning experiences in which learners investigate, manipulate, and come to discover geometric relationships themselves.

Digital tools such as Tinkercad represent the practical application of constructivist principles in contemporary education. Tinkercad provides an interactive virtual three-dimensional space for exploring abstract geometric concepts in a tangible way. Students

will be able to see mathematical relationships that might otherwise remain abstract by constructing, rotating, and transforming digital solids. This kind of hands-on and experiential learning environment is in line with Piaget's emphasis on discovery and development of cognition through active manipulation and experimentation.

Further explanation as to how digital learning environments, such as Tinkercad, foster cognitive growth can be gleaned from Vygotsky's notion of the Zone of Proximal Development. The ZPD is the gap between what the learner can do independently and what they could accomplish with appropriate guidance or scaffolding. In the realm of this model, both Tinkercad and the teacher function as mediating agents, respectively, serving as tools to scaffold learners through the process. While the teacher offers instructional guidance that facilitates reflection and critical thinking, Tinkercad provides them with visual and interactive feedback wherein the hypotheses of learners are tested and misconceptions cleared in real time.

For instance, when students use Tinkercad to construct or deconstruct three-dimensional models of cubes, pyramids, or cylinders, they not only apply the formula in geometry but also reconstruct their understanding through observation and manipulation. Such an iterative process of creating, testing, and refining allows for deeper conceptual development, which completely aligns with the constructivist view that knowledge is continuously built and reshaped through experience.

Ultimately, integrating constructivist learning theory into geometry learning, supported by Tinkercad, enhances engagement, nurtures creativity, and fosters critical and spatial thinking. It changes learners from passive recipients of geometric facts to active participants in knowledge construction, encouraging them to inquire, reason, and reflect.

This approach aligns with the goals of modern mathematics education; problem-solving, collaboration, and higher-order thinking have been identified as key outcomes in developing mathematically literate and innovative learners.

2.1.2 Dual Coding Theory

Dual Coding Theory, introduced by Allan Paivio (1986), describes how human cognition processes information through the interaction of two interconnected systems: the verbal system, related to linguistic information such as words, formulas, and symbols, and the non-verbal system or visual system, which manages images, spatial relationships, and sensory clues. According to this theory, learning will be improved when both systems are being activated simultaneously, enabling information to be encoded in two complementary ways. This dual representation strengthens memory retention and improves learners' retrieval and application of knowledge in various contexts.

This theory is relevant in the study of geometry, as the subject by nature combines symbolic reasoning and visual-spatial understanding. Students are often required to interpret verbal descriptions or mathematical formulas while concurrently visualizing geometric figures and spatial transformations. However, many learners have difficulty in forming connections between abstract concepts, like surface area and volume, and geometric transformations, to concrete visual forms. This tends to create fragmented understanding and difficulty in problem-solving.

Digital learning platforms like Tinkercad have successfully applied Dual Coding Theory in practice by incorporating both verbal and visual learning within the same environment. Tinkercad allows learners to design and manipulate three-dimensional models by assigning real-world dimensions, shapes, and orientations, while referring to the corresponding

mathematical notations and formulas. For example, while building a virtual cube or cylinder, students apply algebraic relationships referring to volume, such as $V = \pi r^2 h$, yet observe visually how changing one dimension affects the overall shape. This integrates the verbal and visual codes, transferring abstract concepts into concrete understanding.

Furthermore, by activating the two coding channels, cognitive integration with Tinkercad strengthens the associations between symbolic and visual information. The students will remember the mathematical principles better as those are associated with vivid visual experiences when manipulating and transforming a shape. For instance, while reading a geometric definition of a prism, its rotation in 3D enhances both linguistic comprehension and spatial reasoning. This interaction decreases cognitive overload, promotes better understanding, and accelerates deeper conceptual learning. The simultaneous activation of the two cognitive systems allows students to develop higher-level thinking; that is, they do not just memorize formulas but reason out, hypothesize, and verify geometric relationships through experimentation. The dual coding environment transforms the learning of geometry into an interactive, multimodal experience in which abstract symbols take on meaning provided by their visual representation.

In sum, Dual Coding Theory stresses the importance of using words and images together for maximum learning. In a geometry class, this idea is implemented through resources such as Tinkercad, which merges the math language with manipulable visual models. This helps students to make stronger connections, retain information longer, and to apply geometric reasoning in and out of the classroom.

2.1.3 Cognitive Load Theory

Cognitive Load Theory, first described by John Sweller in 1988, describes how the structure and presentation of information influence the learner's ability to process, retain, and apply new knowledge. The basis of this theory lies in the concept that the human working memory is of limited capacity, and when instructional materials overload that capacity, learning becomes inefficient. CLT categorizes cognitive load into three kinds: intrinsic load, which arises from the inherent complexity of the content; extraneous load, caused by how information is presented; and germane load, referring to the cognitive effort dedicated to constructing and automatizing meaningful learning schemas.

In geometry, there is a high intrinsic cognitive load imposed by the requirement to visualize, manipulate, and understand spatial structures. The tasks of mentally rotating shapes, interpreting multiple representations, and relating two-dimensional diagrams to three-dimensional objects can easily exceed the limits of working memory. Traditional instruction, reliant on static diagrams and verbal descriptions, may inadvertently increase extraneous cognitive load by placing the burden on the students to mentally simulate spatial relationships without sufficient visual support.

In addition to such challenges, interactive digital tools like Tinkercad reduce extraneous load and encourage germane processing. Real-time visualizations and manipulable 3D models externalize abstract mental imagery in Tinkercad so that learners can explore geometric relations without the necessity to mentally manipulate every transformation internally. For instance, a student is able to rotate, enlarge, or dissect a virtual pyramid on the screen to understand its dimensions and properties, rather than having to imagine such changes. Such interactivity also aligns with Sweller's principles concerning worked

examples and modality effects that call for the inclusion of both visual and kinesthetic aids to alleviate unnecessary mental strain.

Moreover, Tinkercad enhances cognitive efficiency by distributing information across visual and tactile modalities. As students interact with the geometric solids, the platform provides immediate feedback in a guided discovery of misconceptions to refine understanding. This process not only lowers the extraneous cognitive load but also increases germane load, which encourages students to focus their mental effort on constructing durable conceptual frameworks for geometry.

In real classroom practice, this means that learners can devote more of their scarce working memory resources to the tasks at hand—understanding geometric relationships, applying theorems, solving problems—rather than investing effort in interpreting or visualizing complex shapes. The dynamic nature of Tinkercad transforms geometry learning from a purely abstract exercise into an engaging, cognitively manageable experience.

Put differently, Cognitive Load Theory emphasizes that instructional materials should be designed with consideration of human cognitive limitations. Interactions, visuals, and hands-on activity in Tinkercad work to minimize cognitive overload, optimize mental resources, and enhance the learner's ability to process, integrate, and retain geometric knowledge.

2.1.4 Multimedia Learning Theory

Proposed by Richard Mayer in 2001, the Multimedia Learning Theory stresses that active construction of a coherent mental model from information presented through verbal and visual channels is necessary to produce meaningful learning. Mayer argues that

instructional materials should include multiple modes, such as text and narration, images, animations, and interactive models, rather than being limited to a single form of representation. According to this theory, the CTML postulates that humans possess two separate channels for processing information (verbal and visual), each with a different capacity, and that effective learning involves engaging both in a balanced, complementary manner.

This theory assumes a special importance in geometry education since geometric reasoning naturally requires the learner to connect symbolic mathematical language with visual-spatial representations. Traditional instruction often relies on static diagrams or textbook descriptions, which can limit students' engagement and restrict their ability to visualize dynamic spatial relationships. Mayer's principles, such as the multimedia principle, modality principle, and contiguity principle, suggest that when learners experience well-coordinated visual and verbal information, they are likely to make meaningful connections and retain knowledge over time. Tinkercad represents an excellent example of the use of Mayer's Multimedia Learning Theory in practice. On this platform, textual and numerical input, such as dimensions, coordinates, and formulas, is combined with interactive three-dimensional models, enabling students to engage both verbally and visually. For example, as learners design a 3D geometric object, such as a prism or cone, they are able to view the object's dimensions numerically while at the same time observing the object's spatial properties visually. Such coordination of symbolic and visual information helps students form mental bridges between abstract formulas and their geometric representation.

In addition, Tinkercad allows students to reposition objects by rotating, resizing, and combining shapes to see how one variable affects others through its hands-on interactive

environment. Such hands-on engagement turns abstract math concepts into tangible experiences, building active learning and deeper cognitive processing. Allowing them to investigate geometric transformations in real time, they are also encouraged to hypothesize, test out, and reflect on core processes that help them reach meaningful understanding rather than rote memorization.

Furthermore, Tinkercad is designed coherently and contiguously, regarding two more of Mayer's principles. Information, both visual and verbal, is presented close together and synchronously, so that learners will not need to mentally integrate disjointed sources. This reduces unnecessary cognitive load, helping students understand key relationships, for example, between surface area and shape structure, or between volume and dimensional changes.

Fundamentally, Tinkercad's rich media interface transforms learning geometry into an immersive and cognitively intense experience. The blend of text, numbers, images, and interaction leads to richer mental associations, clarifies abstract concepts, and reduces misconceptions. Therefore, using Tinkercad for teaching geometry not only fully conforms to Mayer's Multimedia Learning Theory but also demonstrates that technology has a positive impact on learning, retention, and problem-solving abilities among learners at the junior high school level.

2.1.5 Technology Acceptance Model (TAM)

Among the most influential guides on how users come to accept and effectively use technology is the Technology Acceptance Model, devised by Fred Davis in 1989. Grounded in the Theory of Reasoned Action, TAM suggests that an individual's intention to use a technological system is primarily influenced by two key perceptions: Perceived

Usefulness and Perceived Ease of Use. Perceived Usefulness can be defined as the degree to which an individual believes that using an enabling technology will improve their performance, whereas Perceived Ease of Use is the degree to which one believes that using the technology will be free of effort. These perceptions jointly drive users' attitudes, behavioral intentions, and eventual adoption.

In an educational context, TAM gives insight into how students engage in emerging digital learning tools like Tinkercad. Effective learning and teaching with technology has to be a matter not just of availability or access but also about perception and motivation. It is more likely that students will adopt and actually engage deeply with Tinkercad when they perceive it as useful to enhance their understanding of geometry, and at the same time is easy to use within the learning environment. For example, if learners recognize that using Tinkercad helps them better visualize complex geometric concepts, improve their problem-solving skills, and do hands-on explorations, they perceive usefulness, which in turn encourages continued use.

Perceived ease of use holds great importance for the technology acceptance of students. The intuitive interface, drag-and-drop features, and real-time 3D visualization capabilities make Tinkercad very approachable even to students with very minimal prior experience in computer-aided design. When learners find this tool easy to use, responsive to their inputs, then cognitive barriers decrease, allowing them to focus on learning and not on the mechanics of using the technology. This user-friendly design enhances their confidence, promotes active participation, and increases the likelihood of continued engagement.

Besides that, TAM recognizes the role of attitudinal and motivational issues related to technology adoption. In cases where learners feel successful and satisfied with experiences

using Tinkercad, positive attitudes are reinforced, creating an overall enthusiasm toward both the tool and the mathematics within. Such intrinsic motivation could go beyond the confines of the classroom and spill into a general disposition toward mathematics and learning integrated with technology. Instructors also play an important role in shaping such perceptions through guidance, encouragement, and opportunities for collaborative exploration, which further strengthen students' acceptance and sustained use of the tool.

Finally, applying the Technology Acceptance Model in this study provides insight into how and why students adopt digital platforms like Tinkercad for learning geometry. The model emphasizes that the effective integration of technology is not a question of whether the tool is available but relates to learners' perceptions of its relevance, ease of use, and efficiency in enhancing their academic experience. When students perceive Tinkercad as being useful yet easy to use, they are more likely to engage in it meaningfully and hence will have a better conceptual understanding, resulting in higher motivation and increased academic attainment in mathematics.

2.1.6 Synthesis of Theories

The aforementioned theories, when taken together, help form a comprehensive, multi-dimensional view of how Tinkercad can be effectively used to enhance the teaching and learning of geometry. Each provides a unique yet interrelated perspective that, taken together, gives a rich pedagogical basis to ground digital tools in mathematics education.

From the constructivist point of view, such learning occurs by means of active engagement and interaction. Constructivist Learning Theory, developed by Piaget (1970) and later by Vygotsky (1978), describes how learners construct their own knowledge by exploring, manipulating, and reflecting. In Tinkercad, students do not passively learn about geometric

concepts but, rather, they themselves build, rotate, and change three-dimensional models. Such a process turns the abstract into concrete and allows the students to internalize mathematical concepts by means of self-discovery and experimentation.

The theories of Dual Coding by Paivio (1986) and Multimedia Learning by Mayer (2001) shed further light on how digital visualization enhances understanding. Both theories identify a powerful principle behind learning: combining verbal and visual information enhances learning. In Tinkercad, for example, textual information about the dimensions, coordinates, and formula are combined in a seamless way with dynamic 3D visuals. This ensures that learners process information through both the verbal and visual channels concurrently. This dual processing reinforces deeper understandings, promotes long-term retention, and assists in overcoming the common gap that exists between mathematical symbolism and spatial reasoning in geometry.

The Cognitive Load Theory by Sweller (1988) contributes another dimension by addressing efficiency in cognitive processing. Geometry intrinsically requires heavy mental work because students have to create an image of spatial structures and manipulate them in their minds. Tinkercad relieves this burden by externalizing the cumbersome mental imagery, letting students manipulate virtual models directly rather than rotating or visualizing them mentally. This reduction in extraneous cognitive load frees up mental resources for more meaningful learning activities, such as investigating geometric relationships and applying mathematical reasoning.

Finally, the Technology Acceptance Model (TAM) by Davis (1989) offers a behavioral and motivational perspective on the way learners use educational technology. Students are likely to accept and learn more with Tinkercad when they perceive the technology as useful

in enhancing their knowledge in geometry and find it easy to handle within the learning environment. The intuitive design of the platform, combined with visible learning benefits, creates motivation, confidence, and positive attitudes toward mathematics-necessary ingredients for sustained engagement and academic success.

When synthesized, these theories reveal that Tinkercad is far more than a technological supplement; it is a pedagogical instrument grounded in well-established cognitive and motivational principles. It functions as both a cognitive scaffold, supporting visualization, problem-solving, and conceptual integration, and a motivational tool, encouraging curiosity, autonomy, and persistence. This holistic theoretical framework positions Tinkercad as an effective medium through which geometry instruction can evolve from abstract and static learning to interactive, experiential, and student-centered engagement.

In conclusion, the integration of these theories underlines that the educational value of Tinkercad results from a strong interconnection between the constructivist, cognitive, and technological dimensions of learning. Tinkercad simultaneously affords active construction of knowledge, dual-channel processing, cognitive efficiency, and positive technology adoption; hence, it provides a powerful, theory-driven path toward improving geometry understanding and performance in junior high school students.

2.2 Empirical Review

Several empirical studies have investigated the impact of Tinkercad and similar computer-aided design (CAD) tools on students' achievement and understanding of geometry concepts, revealing substantial evidence that digital modeling can significantly enhance spatial reasoning, visualization, and problem-solving abilities among junior high school

learners. In a quasi-experimental study, Pielsticker (2021) examined the effect of Tinkercad on geometric reasoning among elementary students, focusing on the development of three-dimensional thinking and solid geometry comprehension. The experimental group, which used Tinkercad to design and manipulate 3D geometric objects, demonstrated markedly higher post-test scores compared to their peers who relied solely on textbook-based instruction.

The study concluded that Tinkercad's interactive environment, which allows for real-time visualization and modification of geometric solids, bridges the gap between abstract mathematical concepts and tangible understanding, thereby improving performance in geometry-related tasks such as surface area, volume, and spatial orientation. Similarly, Bhaduri, Umopathy, and Dutta (2021) conducted an observational and process-tracing study that analyzed middle school students' modeling behaviors while using Tinkercad. Through analysis of screen recordings and student reflections, they discovered that Tinkercad supported iterative design thinking and fostered deeper engagement with geometric transformations, specifically rotation, scaling, alignment, and symmetry. Students were found to be actively constructing mental models of spatial relationships, which are essential for success in geometry. Although the study did not directly measure standardized test achievement, it empirically demonstrated that students' interaction with Tinkercad strengthened the cognitive processes underlying geometric reasoning. Building upon these findings, Erdogan et al., (2023) employed a mixed-method design to evaluate the usability and educational impact of Tinkercad among secondary school students in Turkey. Over a three-week instructional intervention, students participated in guided geometry projects involving modeling and measuring shapes using Tinkercad's digital

tools. Quantitative analysis revealed significant improvements in students' geometry test scores after the intervention, while qualitative data from interviews and observations highlighted increased confidence, motivation, and collaboration during problem-solving. The researchers emphasized that Tinkercad's simplicity, visual appeal, and alignment with geometry curriculum standards make it a practical tool for classroom integration.

Additional evidence by Barbosa, Pereira, and Costa (2024) showed that Tinkercad and 3D printing integrated into a STEAM context promoted relevant advances in the development of students' spatial and geometric reasoning. In an experimental study with junior high students and pre-service teachers, the authors reported that students gained a deeper understanding of such geometric relationships as congruence, similarity, and proportionality. Students were found to be much more creative and interested when asked to design a model that integrated theoretical knowledge of geometry and thus could connect abstract reasoning to practical design tasks. These findings emphasized how Tinkercad has the potential to enhance the learning of geometry based on experiential, hands-on digital modeling.

Beyond these individual studies, broader empirical reviews provide supporting evidence for the role of CAD and 3D modeling tools in mathematics education. Ng et al. (2022), in a scoping review encompassing over sixty empirical studies, concluded that 3D printing and modeling environments such as Tinkercad enhance mathematical learning by enhancing visualization, spatial ability, and conceptual understanding of geometry. The review found that across multiple grade levels, students who used the 3D modeling tools attained higher scores on geometry assessments and viewed mathematics more favorably. Similarly, Dilling (2021) examined how CAD software influences spatial ability strong

predictor of geometry achievement reported that middle school students using CAD tools performed significantly better in spatial visualization and mental rotation tasks compared to those in traditional learning settings.

These empirical studies collectively provide strong evidence that Tinkercad positively influences students' achievement in geometry by offering them an active, visual platform that enhances spatial reasoning, problem-solving, and geometric understanding. The use of Tinkercad changes abstract geometric concepts into concrete experiences through which the student can explore relationships, manipulate 3D objects, and test their thinking by designing and taking measurements. However, amidst these promising results found across various contexts, the literature also signals a real gap: few large-scale experiments have focused exclusively on junior high school students or measured longer-term retention of geometry knowledge beyond Tinkercad-based instruction. Consequently, future empirical work should consider longitudinal and comparative analyses to determine causality between Tinkercad integration and sustained improvements in geometry achievement.

2.3 Conceptual Framework

The following is a conceptual framework for this study, which has been done to show how the integration of Tinkercad, a 3D modeling tool, will influence junior high school students' achievement in geometry. This theoretical framework is grounded in well-established learning theories, emphasizing active engagement, visualization, and technology integration in education. Based on the framework, it is assumed that once the students have gone through the instruction based on Tinkercad, their interactions with 3D models enhance spatial reasoning and conceptual understanding, boosting overall performance in geometry.

It is supported at its core by the Constructivist Learning Theory of Piaget (1970) and Vygotsky (1978), where learners cognitively construct knowledge through an active process of interacting with their environment. Geometry learning, being inherently spatial and visual, benefits greatly from tools that allow exploration and manipulation of shapes. Tinkercad provides this interactive platform, whereby students can design, rotate, and then visualize geometric solids to facilitate much deeper cognitive engagement. ZPD further supports the idea that technological scaffolds such as Tinkercad guide students through more complex tasks than they are able to complete themselves, foster incremental mastery of geometric concepts.

Moreover, the Dual Coding Theory by Paivio (1986) gives evidence of cognitive advantages of verbal and visual data combination during instruction. Geometry deals with the understanding of abstract mathematical terms and their visual representation simultaneously. Tinkercad fills in this gap by translating the abstract symbols and formulas into manipulable 3D forms that strengthen comprehension and memory retention. Cognitive Load Theory by Sweller (1988) also explains Tinkercad's ability to reduce extraneous mental effort through intuitive visual cues so learners can focus on essential problem-solving rather than struggling with abstraction.

This framework further integrates the Multimedia Learning Theory of Mayer (2001), which maintains that productive learning occurs when visual and verbal information is co-activated. Tinkercad epitomizes this integration by providing ways for learners to visualize mathematics problems as they receive verbal or written explanations. Such duality in engagement enhances conceptual clarity and, hence, long-term retention of the concepts learned in geometry. Finally, the Technology Acceptance Model (TAM) of Davis (1989)

puts a premium on the perceptions of the students themselves through the perceived usefulness and perceived ease of use of Tinkercad in determining how well students will accept and profit from it as a tool for learning.

In this study, Tinkercad is the independent variable, being the technological intervention that is introduced into geometry instruction. Students' engagement and participation are the mediating variables to capture how the use of Tinkercad influences learners in terms of motivation, interaction, and visualization during lessons. The dependent variable of the study is students' academic achievement in geometry, as assessed by test scores and performance assessments after intervention. The hypothesized relationship among these variables is as follows: Integration of Tinkercad within geometry instruction enhances students' engagement and spatial reasoning, which, in turn, boosts achievement outcomes.

In summary, the conceptual framework postulates that Tinkercad mediates between the abstract geometric theory and its practical visualization and accordingly enhances higher cognitive processing for better performance. Such a cognitive-constructivist-technological explanation shows exactly how digital modeling tools can turn geometry learning from a passive, memory-based activity into an interactive, experience-based process.

2.4 Effectiveness of Tinkercad on junior high school students' performance in geometry

The effectiveness of Tinkercad on junior high school students' academic performance in geometry is one of the most discussed topics in recent educational research, especially when considering the inclusion of technology in mathematics education. Works range from highlighting digital tools as both supportive and obstructive to students' mathematical

understanding and engagement. A study was conducted to investigate the effectiveness of Tinkercad in influencing the performance of students in geometry, with an emphasis on how the students learn and the critical role that technology might play in mathematics education. This initial study laid the foundation for further research on how digital tools can support learning processes at school, particularly in geometry. The next outstanding work is that of Shadaan & Leong (2013), who presented the effectiveness of GeoGebra software, although not directly on Tinkercad, joining the discussion of technology in enhancing students' conceptual understanding in mathematics. According to the findings, the use of computer activities enables the development of higher-order thinking skills and encourages students—a finding which agrees with the potential benefits of using Tinkercad as a tool for learning. Sinclair et al. (2016) add weight to the discussion by discussing the importance of choosing appropriate digital technologies in an educational setting. They elaborated on the approach of instrumental genesis, which gives an emphasis on how students engage in mathematical tools—a concept quite relevant for Tinkercad application in geometry education.

In 2018, Cairns et al. presented the emergent use of 3D fabrication in middle school, using mathematics and technology in ways that provide authentic design projects, which Tinkercad is able to facilitate. This study underlined how such tools could promote deep learning by connecting theoretical concepts to real-world applications, which is crucial for understanding geometry. Oluseyi Adenubi (2018) supported this idea when he managed to show that 3D figures enhance students' in their polyhedral and suggested that visual and interactive tools like Tinkercad work for teaching complex geometric notions. Ouelini (2019) expanded on the benefits of technology within the classroom by researching

intelligent tutoring software and found that these types of tools can improve student engagement in, and achievement of, geometry. It follows from this that Tinkercad might, as an easy-to-use platform, encourage positive attitudes and improved performance from its use by junior high school students. Bhaduri et al. (2021) discussed how 3D modeling and augmented reality enhance spatial thinking—a basic skill in geometry. Their findings support the idea that tools like Tinkercad can facilitate learning by encouraging hands-on experiences and interactive problem-solving to improve students' spatial reasoning. Later in that same year, Shaghaghian et al. (2021) proposed an AR-powered approach to teaching geometric transformation, with an emphasis on the difficulties that students usually face with this subject when taught traditionally. Their work indicates that innovative technological interventions have the potential to bridge the gap in understanding and support the use of Tinkercad in enhancing geometry. Finally, Erdogan et al. (2023) conducted a usability study on the Tinkercad platform, confirming its effectiveness and ease of use for teaching coding and robotics. Their findings suggest that Tinkercad is beneficial not only because it is user-friendly but also for enhancing the algorithmic skills of students, something particularly welcomed in geometry and other mathematical subjects.

Overall, the literature reviewed develops a strong argument on how Tinkercad and similar digital tools can increase the academic performance among junior high school students in geometry. The review has, from different research works, demonstrated that the incorporation of technology into math lessons could facilitate deeper engagement, understanding, and application of geometrical concepts.

2.5 Gender differences in students' performance when taught geometry using Tinkercad

This domain of the investigation of gender differences in students' geometry performance using new approaches, including Tinkercad, is heterogeneous and has attracted considerable interest in recent years. The following literature review covers the main results in this period and develops a complex picture of gender dynamics in mathematical performance, centered on the aspects connected with geometry education.

Mainali (2014) contributes the foundational literature to the gender-geometry performance relationship and notes inconsistent evidence from multiple studies. While some countries show significant differences in gender geometry performance, others show no apparent disparities. Inconsistency indicates that factors other than gender, such as educational practices and cultural contexts, can affect mathematical outcomes. These findings highlight the importance of representation of problem-solving methods, as students have preferences for visual or verbal methods that influence their results. To extend this view, Katsioloudis et al. (2016) examine the effectiveness of instructional methods in 3D Computer-Aided Design (CADD) software to enhance student spatial abilities. Based on their research findings, the difference in teaching methods, especially teacher-centered, can lead to varying results of student performance in spatial reasoning tasks. This points to constructivist theories, which are characterized by learner-centered methodologies. Because of these reasons, there is a possibility that gender differences in spatial ability could be reduced with an effective instructional strategy intervention.

Sinclair et al.(2016) further contributed to this discourse by examining the role of digital technologies in early mathematics education. They emphasize that the effects of technology

on student learning are not uniform, highlighting the need for thoughtful integration of digital tools in the curriculum. Their review suggests that the affordances of digital technologies can enhance students' engagement and understanding of geometric concepts, potentially influencing gender-related performance differences. Reyes (2017) delves into the spatial reasoning processes that underpin students' ability to engage with STEM disciplines. He notes that spatial skills are critical predictors of success in these fields and challenges the notion that males inherently possess superior spatial abilities. His findings indicate that experiential factors and targeted training can significantly enhance spatial reasoning skills among all students, thereby addressing gender disparities. Smith & Talley (2018) present evidence of improvements in spatial visualization skills through hands-on projects, such as 3D printing in engineering courses. Their work highlights the importance of practical engagement in developing spatial skills, suggesting that such experiences can help bridge the gender gap in STEM education by fostering equal opportunities for skill development.

In a similar vein, Spieler & Slany (2018) discuss the accessibility of programming through visually oriented tools, advocating for environments that are conducive to female engagement in computing. They argue that fostering creativity and interest in STEM through tailored learning experiences can positively influence young women's career aspirations in these fields. The subsequent study by Spieler et al. (2019) reinforces this notion by examining the behaviors of female students in computer science classes. Their findings reveal persistent gender gaps in engagement and interest, suggesting that educational practices must evolve to create more inclusive environments that cater to diverse learning preferences. Bhaduri et al. (2021) focus on the role of spatial thinking in

STEM achievement, emphasizing the potential of 3D modeling and augmented reality as tools for enhancing spatial skills.

Their research highlights the importance of integrating technology in ways that promote active learning and engagement, which may help to alleviate gender disparities in performance. Finally, the paper of Shaghaghian et al. (2022) contributes to the understanding of spatial transformation in mathematics with augmented reality applications. Their findings further solidify the need for novel teaching tools that may allow for a deeper understanding of geometric concepts and be useful in overcoming several open issues related to the different genders of students.

This literature review will synthesize these articles to develop a comprehensive understanding of gender differences in geometry performance, with an emphasis on the critical role played by instructional methods, digital technologies, and spatial reasoning in shaping educational outcomes.

2.6 Students' Attitudes toward Learning Geometry Using Tinkercad

Literature on students' attitudes towards learning geometry using Tinkercad shows a multi-dimensional study of how different aspects of digital tools and pedagogical strategies can influence students' knowledge of mathematics and their attitudes toward the discipline. The early work of Burton Foster (2013) emphasized the necessity of distinguishing between ease of calculation and deeper understanding in statistical literacy, noting that while tools such as Tinkerplots make calculation easier, use of the tool does not necessarily imply improvement in understanding. This realization puts additional responsibility on the teacher to clearly explain the pedagogical rationale for using technology in mathematics

education. On the foundation laid by the pioneer in the field, Viljoen & Van Schoor (2015) also explore 3D Computer-Aided Design as a tool to teach three-dimensional drawings, focusing on blended learning methodologies that enhance students' potential for creativity and confidence. According to these researchers, when students are engaged in an innovative approach, their application of higher-order thinking skills is improved, especially those skills that are necessary for geometric competence. This is in line with views that keeping students' interest facilitates deeper approaches to learning Batmunkh (2016) further expands on the role of physical modeling in design education, claiming that the experience of building models would prevent design fixation and thus promote more productive learning. This view underlines the importance of hands-on experiences in geometry and provides further support to our idea that the introduction of physical models will contribute to the deeper acquisition of geometric knowledge.

Sinclair & Baccaglini-Frank (2016) contribute to this discussion by summarizing how digital technologies can affect mathematics learning at the K-2 level. Their review suggests that while the impact of technology on achievement is complex, tools like interactive software and virtual manipulatives have the potential to substantially improve students' geometrical understanding, especially if these tools are combined with other sound pedagogical practices. Cairns et al. (2018) take the STEAM approach—one that links mathematics to real-world applications, encourages students to explore 3D design in geometry classes, and introduces the use of 3D printing. This, they argue, enables students to engage in more authentic tasks that make their learning of the concept of geometry deeper; this, in turn, promotes a more holistic approach to learning the subject. Duncan Valentine (2018) points out that such tinkering and experimentation with geometry can also

be done through coding environments like Logo. By encouraging students to try different things, they can arrive at a deeper understanding of spatial relationships and geometric principles, reflecting the theory of constructionism, which posits that making is one of the most important activities for learning. More recent technology developments are discussed by Bhaduri et al. (2021), who demonstrate the potential of Augmented Reality (AR) to enhance students' spatial thinking skills via 3D modeling. According to their findings, AR allows students to come up with engaging experiences that connect abstract geometric ideas to a more concrete understanding. Shaghaghian et al. (2021) extend the application of AR in the teaching of geometric transformations to propose that, through the use of interactive tools, deeper understandings of complex mathematical concepts can be achieved, whereby students visualize and manipulate geometric relationships in a dynamic manner.

Carmona-Medeiro et al. (2021) have explored the learning prospects of SketchUp and found that such software provides advantages in terms of the students' spatial abilities, but it depends on the preparedness of teachers and pedagogical methodology. This also means educators make the most critical difference in how technology enhances understanding among the learners. Finally, Erdogan et al. (2023) have offered a current insight into the usability of Tinkercad and proved that this platform can facilitate an effective engagement of students with their abstract ideas and provide them with hands-on activity learning. Their results supported the fact that usability is an important aspect of educational tools; thus, their good design might significantly improve both engagement and students' creative performance in geometry.

Overall, this review shows the changing landscape of geometry teaching and learning, focusing on the interdependence between technology and pedagogy in creating the best learning environments to help students better understand geometric conceptions with tools such as Tinkercad.

2.7 Summary of Literature Review

Various scholars have researched the incorporation of digital tools and visualization techniques in mathematics and geometry education and have found some advantages in teaching and learning. For example, Burton Foster (2013) researched the effectiveness of Tinkerplots in enhancing preservice elementary teachers' understanding of measures of center and graphical representations and reported that Tinkerplots significantly enhanced teachers' understanding of data interpretation, hence having the potential to support conceptual understanding in mathematics with the use of similar tools such as Tinkercad. In a different study, Viljoen and Van Schoor (2015) explored the use of a blended teaching and learning approach for three-dimensional drawings instruction and found that in combining traditional and digital approaches, students' spatial abilities and technical drawing skills improved, thus supporting the use of 3D tools in learning related to geometry.

Further contributing to this field, Eryilmaz and Deniz, in their 2021 study, investigated the effect of Tinkercad on middle school students and reported that Tinkercad significantly enhanced the computational thinking skills and engagement of students, thus directly aligning with the present study's objective of assessing the impact of Tinkercad on geometry performance. On the other hand, Mainali (2014) focused on geometry education and analyzed how preferences and gender influence high school students' geometry

performance, finding differentiated outcomes based on these influencing factors, thereby serving as important guidelines in consideration of possible variation in geometry learning, which may inform further utilization of digital tools.

In the Ghanaian context, Sam et al. (2024) assessed factors influencing geometry achievement in senior high schools and found that instructional methods and students' attitudes significantly affected learning outcomes, providing a critical local context for evaluating new tools like Tinkercad in Ghanaian schools. Finally, Fokuo et al. (2023) conducted a systematic review on the use of visualization tools in teaching mathematics in Colleges of Education and concluded that visualization tools enhance students' understanding of abstract mathematical concepts and increase motivation, pointing out that Tinkercad is one such useful resource in the teaching of geometry. Overall, these studies reveal the role that employing digital and visualization tools such as Tinkercad can play in bolstering learning in geometry by improving academic performance and reducing motivational problems, especially in diverse educational environments like Ghana.

2.8 Conclusion

The review of the related literature provided a thorough overview of how technological innovations, especially Tinkercad, contribute to enhancing students' achievement in geometry. From theoretical and empirical standpoints, it is clear that integrating digital tools into mathematics teaching and learning enhances students' engagement, spatial reasoning, and conceptual understanding. These five theoretical frameworks, upon which this study is based, namely Constructivist Learning Theory, Dual Coding Theory, Cognitive Load Theory, Multimedia Learning Theory, and the Technology Acceptance Model, all support the central idea of active, visual, and technology-mediated learning. They all

suggest that when students interact with virtual modeling environments like Tinkercad, they are best placed to construct knowledge, visualize geometric relationships, and connect abstract mathematical concepts to concrete representations. In other words, Tinkercad acts like a cognitive scaffold, enabling exploration, visualization, and problem-solving for meaningful and lasting learning in geometry.

Empirical evidence reviewed further supports these theoretical assertions. Studies by Pielsticker (2021), Bhaduri et al. (2021), Erdogan et al. (2023), and Barbosa et al. (2024) indicate that the use of Tinkercad and similar 3D modeling platforms results in improved student performance in mathematics and geometry. The tools have been found to enhance active learning, collaboration, and creativity while reducing the cognitive barriers often associated with abstract mathematical instruction. Outcomes from these studies have shown that Tinkercad presents an intuitive and user-friendly platform through which students can design, manipulate, and analyze three-dimensional objects-central skills for mastering geometric concepts of shape properties, measurement, congruence, and transformations. Reviews by Ng et al. (2022) and Dilling (2021) further indicate that CAD tools improve spatial visualization and reasoning-considered major predictors of students' performance in geometry.

These promising findings notwithstanding, the literature points to some significant gaps that justify the current investigation: most of the existing studies have been done for developed countries with advanced technological infrastructure, leaving limited evidence from developing contexts such as Ghana, where access to educational technology is still emerging; secondly, only a few of these studies have targeted junior high school learners, although this stage is crucial in the development of foundational geometric reasoning. In

addition, most of the prior research has been descriptive rather than experimental; thus, this is a limitation in determining causality between Tinkercad integration and improved academic achievement.

In a nutshell, the theories and studies reviewed provide a concrete foundation for the present study in their demonstration that Tinkercad can make learning geometry more interactive, engaging, and effective. Where theoretical and empirical evidence converge, it would appear that Tinkercad's 3D modeling could help narrow the gap between abstract mathematical ideas and students' real-world comprehension. However, no sufficient empirical studies have been conducted within the Ghanaian junior high school context, which provides room for further exploration. This study, therefore, seeks to fill this gap by empirically testing how integrating Tinkercad into students' geometry instructions affects their academic achievement and whether such influence varies across gender. In fact, the findings are likely to add to the increasing literature on technology integration in mathematics education and offer practical insights to enhance geometry teaching and learning in Ghanaian schools.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Overview

This chapter describes the research methods used to investigate the effect of Tinkercad on Junior High School students' performance in geometry. It explains the research design chosen for the study and provides details about the setting, the target population, and how participants were selected. The chapter also outlines the instruments used for data collection, including questionnaires and tests, and describes how these tools were validated and pretested to ensure accuracy and reliability. Furthermore, it highlights the procedures for data analysis and discusses the ethical considerations observed to protect participants' rights and confidentiality. Together, these sections establish the systematic approach taken to gather and analyze data in order to address the research objectives and hypotheses effectively.

3.1 Research Design

The study used a quasi-experimental pretest-posttest control design to assess the effect of Tinkercad on students' performance on Junior High School. One group was taught geometry using Tinkercad (experimental group), and the other with traditional methods (control group). A pre-test and post-test were used to measure the effect of Tinkercad on

students' performance. The design also helped examine gender differences and students' attitudes toward using Tinkercad. 3.2 Target Population

Random assignment was not possible, so two intact JHS classes (N=80) from two private schools in Accra, Ghana (British Columbia College and Penfield Junior High School) was used, 29 in the experimental group and 51 in the control group. Both groups had balanced gender representation. This group was selected because they are at a critical stage of developing spatial reasoning and foundational mathematical skills. Their exposure to digital tools like Tinkercad offers an opportunity to assess how technology can influence learning outcomes in geometry.

3.4 Data Collection Instruments

In this study, two research instruments were employed to gather relevant data on the effect of Tinkercad on Junior High School students' performance in geometry. These tools included a structured questionnaire, achievement tests (pretest and posttest). The structured questionnaire was designed to assess students' attitudes toward learning geometry using Tinkercad, focusing on areas such as interest, motivation, ease of use, engagement, and perceived usefulness. It included both closed-ended questions (like Likert scale items) and open-ended responses to gather in-depth feedback. The achievement tests, consisting of a pretest and a posttest, were used to measure students' academic performance in geometry before and after the intervention. This allows for comparison between the experimental group (taught with Tinkercad) and the control group (taught using traditional methods). The questions in these tools were adopted from validated instruments such as the Mathematics Attitude Inventory (MAI) and those based on the Technology Acceptance

Model (TAM), which have been used in studies measuring students' perceptions of digital tools.

Geometry test questions were adapted from the Ghana Education Service (GES) mathematics syllabus and past Basic Education Certificate Examination (BECE) papers to ensure curriculum alignment. Additionally, questions may be drawn from previous research studies like those by Eryilmaz and Deniz (2021), Cairns et al. (2018), and Sam et al. (2024), which focused on digital tools and students' performance in geometry. These sources provided a solid foundation for developing reliable and contextually appropriate research instruments.

3.5 Reliability of the Instruments

Reliability refers to the consistency and dependability of a research instrument in measuring what it is intended to measure over time. In this study, reliability was ensured through several procedures applied to the instruments used, namely, the structured questionnaire, and achievement tests. For the structured questionnaire, a pilot study was conducted with a group of students similar to the target population to test the clarity, coherence, and internal consistency of the items. The responses from the pilot test were analyzed using Cronbach's alpha, a statistical measure commonly used to determine the reliability of survey instruments. A Cronbach's alpha coefficient of 0.70 or higher was considered acceptable for confirming the internal consistency of the questionnaire items. For the achievement tests (pretest and posttest), reliability was established by using well-constructed items aligned with the Junior High School mathematics curriculum and validated by mathematics education experts. These items were reviewed to ensure that they appropriately measure students' understanding of geometry and consistently produce

similar results when applied in similar contexts. Through these procedures, the study maintained a high level of instrument reliability, increasing the credibility of the data collected and the validity of the conclusions drawn.

3.6 Data Collection Procedure

The data collection procedure for this study was carried out in a systematic and organized manner to ensure the accuracy and reliability of the findings. The experimental group received geometry instruction using Tinkercad using laptops, while the control group was taught using traditional methods involving direct teacher exposure and board work over a period of four-weeks.

The same teacher handled both groups and lessons were delivered at the same time of the day to reduce variation. Instructional content, timing and objectives were maintained across groups; the main difference is the instructional delivery method. To reduce biases among the two groups, classes were scheduled separately with no overlap.

3.7 Data Analysis Procedure

The scores from the pretest and posttest will be collected, organized, and entered into a statistical software package IBM SPSS Version 27 for analysis. Descriptive statistics were used to summarize students' test scores and responses to the questionnaire. These summaries will provide an overview of performance levels and students' attitudes toward learning geometry.

To determine whether there was a statistically significant difference in students' academic performance after the intervention, a paired sample t-test was conducted within each group (experimental and control) to compare their pretest and posttest scores. This helped to

assess whether each teaching method (Tinkercad vs. traditional) had a significant effect on students' learning outcomes. Additionally, an independent sample t-test was used to compare the posttest scores between the experimental and control groups to evaluate the effect of Tinkercad compared to traditional instruction. The same test was used to examine any gender differences in geometry performance within the experimental group.

For the structured questionnaire, students' responses to closed-ended items were analyzed using averages and percentages to describe their attitudes toward using Tinkercad. Inferential analysis, such as an independent t-test, was also applied to compare attitudes between the Tinkercad group and the traditional group.

3.8.1 Variables

In this study, variables are classified into three main types: independent variables, dependent variables, and control variables, each playing a specific role in measuring the effect of Tinkercad on junior high school students' performance in geometry.

The independent variable is the instructional method used to teach geometry. This has two levels: the use of Tinkercad (experimental group) and traditional teaching methods (control group). It is the variable that the researcher manipulates to observe its impact on students' academic outcomes and attitudes.

The dependent variables are the outcomes being measured in the study. These include students' academic performance in geometry, measured through pretest and posttest scores, and students' attitudes toward learning geometry, measured through responses to a structured questionnaire. These variables are expected to change based on the type of instructional method used.

The control variables are factors that are kept constant to avoid influencing the results. These include the curriculum content, the duration of instruction, the school environment, and the teacher delivering the lessons. By controlling these factors, the study aims to ensure that any observed differences in student performance and attitudes are due to the instructional method and not external influences.

Together, these variables help the researcher systematically assess the effect of Tinkercad on geometry learning and ensure that the study findings are valid, reliable, and meaningful.

3.8.2 Control of Extraneous Various Variables

In this study, several strategies were employed to control extraneous variables that could otherwise influence students' performance in geometry and their attitudes toward learning.

First, to control instructional differences, the same teacher delivered geometry lessons to both the experimental and control groups to ensure consistency in teaching style, classroom management, and content delivery. The teacher also followed a standardized lesson plan aligned with the curriculum to minimize variations in instructional quality.

Second, lessons were conducted in comparable classrooms under similar conditions (e.g., class size, duration, and time of day) to reduce the influence of environmental factors on student engagement and performance.

Third, to address potential differences in students' prior knowledge, a pretest was administered before the intervention to assess baseline performance. This allows the researcher to compare the two groups' initial abilities and account for any disparities in the final analysis.

Additionally, the curriculum content taught to both groups was identical, ensuring that any observed differences in outcomes are not due to variations in what is taught but rather how it is taught.

Other personal factors, such as students' access to technology, motivation levels, and study habits, was controlled by ensuring that all students in the experimental group have equal access to devices and are guided equally during Tinkercad sessions.

3.9 Ethical Considerations

Before the study begins, ethical clearance was obtained to ensure that the research follows proper guidelines and respects the rights of all participants. Approval was sought from the appropriate educational authorities, including the school administration at British Columbia College and Penfield Junior High School.

Informed consent was obtained from the students. This means that participants were clearly informed about the purpose of the study, what it involves, and their right to withdraw at any time without any consequences.

Confidentiality and privacy were strictly maintained. Students' names did not appear in any reports, and all data collected will be kept secure and used only for the purpose of this study. The research ensured that no harm comes to the students, and all activities, including the use of Tinkercad, was conducted in a safe and supervised environment. The study fully adhered to ethical standards in educational research to protect the dignity, rights, and welfare of all participants.

3.10 Limitations of the Study

The findings of this study are limited by the small sample size, as data were collected from only two private schools in Accra. This limits the extent to which the results can be generalized to all Junior High Schools in Ghana. In addition, the study relied on a quasi-experimental design, which did not allow for random assignment of participants to experimental and control groups. Consequently, some uncontrolled variables such as differences in prior knowledge, teacher experience, and access to digital resources may have influenced the results. Despite these limitations, the study provides useful evidence on the potential of Tinkercad to support the teaching and learning of geometry at the Junior High School level.



CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Overview

This chapter presents the results and discussion of the study based on the data collected from students who participated in the research. It begins with an analysis of the biographical data of the participants, focusing on gender distribution across the experimental and control groups. This section ensures that the sample was balanced and free from gender bias that could affect the interpretation of results.

Following the demographic analysis, the chapter addresses each research question in detail. It presents quantitative data on students' academic performance before and after the intervention, comparing the effectiveness of Tinkercad-based instruction with traditional teaching methods. Statistical analyses, including independent and paired samples t-tests, were used to determine whether there were significant differences in test scores and attitudes across groups and by gender.

The chapter also explores students' attitudes toward learning geometry using Tinkercad, based on responses to a structured Likert-scale questionnaire and open-ended feedback. Graphs, tables, and descriptive statistics are provided to support the findings, and each result is discussed in the context of the research objectives.

4.1 Analysis of Biographical Data of Students

A total of 80 students took part in the study, evenly split between male and female students. Table 1 reports the overall gender distribution, while Table 2 breaks down the gender composition by study group (experimental and control).

4.1.1 Gender of Students

Table 1: Gender Distribution of Students (n = 80)

Gender	Frequency	Percentage (%)
Female	40	50.0
Male	40	50.0
Total	80	100.0

Source: Fieldwork Data (2025)

The results in Table 1 show that the sample was evenly distributed between male and female students. Out of the 80 respondents, 40 (50.0%) were female and 40 (50.0%) were male, indicating a balanced gender representation in the study population.

4.1.2 Gender distribution by study group

Table 2 Gender Distribution by Study Group

Group	Female (n, %)	Male (n, %)	Total (n)
Experimental	16 (55.2)	13 (44.8)	29
Control	24 (47.1)	27 (52.9)	51
Total	40 (50.0)	40 (50.0)	80

Source: Fieldwork Data (2025)

The results in Table 2 show the gender distribution across the experimental and control groups. In the experimental group, females constituted 55.2% (n = 16) while males made up 44.8% (n = 13) of the 29 students. Conversely, in the control group, males were slightly

more represented, accounting for 52.9% (n = 27), compared to females who constituted 47.1% (n = 24) out of 51 students. Overall, the total distribution between genders remained balanced, with both females and males equally represented at 40 each (50.0%).

4.2 Analysis of Research Questions

4.2.1 Research Question One: What is the effect of Tinkercad on Students' Performance?

To answer the research question, the study compared pre- and post-test scores (0–5) on five multiple-choice items. Participants were assigned to an experimental group (instruction with Tinkercad) or a control group (traditional instruction). To evaluate the effect of the intervention, independent and paired samples t-tests were performed and are reported in Tables 3–5.

Table 3: Independent samples t-test analysis of the mean post-test scores of the Experimental and Control groups

Groups	N	d. f	Mean	SD	t-value	P-value
Experimental	29	62	1.59	0.95	–2.002	0.0496
Control	51	62	2.04	1.02		

Source: Fieldwork Data (2025)

The independent samples t-test compared the post-test means of the experimental and control groups. The control group achieved a significantly higher mean score than the experimental group ($p < 0.05$).

Table 4: Paired samples t-test analysis of pre- and post-test scores in the Experimental Group

Test (Exp group)	N	d. f	Mean	SD	t-value	P-value
Pre-test	29	28	1.45	0.83	-0.519	0.608
Post-test	29	28	1.59	0.95		

Source: Fieldwork Data (2025)

The paired samples t-test compared the pre-test and post-test scores of the experimental group (n = 29). The mean pre-test score was 1.45 (SD = 0.83), while the mean post-test score was slightly higher at 1.59 (SD = 0.95). However, the difference between the two means was not statistically significant ($t(28) = -0.519$, $p = 0.608$). Since the p-value is greater than 0.05, this suggests that the intervention did not produce a significant improvement in scores within the experimental group.

Table 5: Paired samples t-test analysis of pre- and post-test scores in the control group

Test (Control group)	N	d. f	Mean	SD	t-value	P-value
Pre-test	51	50	1.20	1.13	-4.285	0.0001
Post-test	51	50	2.04	1.02		

Source: Field Data (2025)

These analyses indicate that the experimental group's mean score increased from 1.45 to 1.59; however, this change was not statistically significant ($t = -0.519$, $p = 0.608$). In contrast, the control group's mean improved from 1.20 to 2.04, which was statistically significant ($t = -4.285$, $p = 0.0001$). An independent samples t-test (Table 3) showed that the control group performed better on the post-test than the experimental group ($p = 0.0496$).

4.2.2 Research Question 2: What are the gender differences in students' performance when taught geometry using Tinkercad?

To answer the question, gender differences were examined within both the experimental and control groups. Table 6 shows the independent samples t-test analysis of the mean post-test scores for male and female students in the experimental group.

Table 6: Independent samples t-test analysis of the mean post-test scores of male and female students in the experimental group

Experimental Group	N	d. f	Mean	SD	t-value	P-value
Males	13	26.7	1.46	0.78	-0.655	0.518
Females	16	26.7	1.69	1.08		

Source: Field Data (2025).

Male students (n = 13) had a mean post-test score of 1.46 (SD = 0.78), whereas female students (n = 16) averaged 1.69 (SD = 1.08). The analysis demonstrates that there was no significant difference in post-test scores between male and female students ($t = -0.655$, $p = 0.518$), indicating that gender did not moderate the effect of the intervention.

Table 7: Independent samples t-test analysis of the mean post-test scores of male and female students in the control group

Control Group	N	d. f	Mean	SD	t-value	P-value
Males	27	48.9	2.22	1.09	1.39	0.172
Females	24	48.9	1.83	0.92		

Source: Field Data (2025).

Among control group students, males (n = 27) achieved a mean post-test score of 2.22 (SD = 1.09), while females (n = 24) averaged 1.83 (SD = 0.92). This difference was not statistically significant ($t \approx 1.39$, $p = 0.172$), suggesting that gender did not influence post-test performance in the control group either.

4.2.3 Research Question 3: What are students' attitudes toward learning geometry using Tinkercad?

Students completed an eight-item Likert-scale questionnaire (1 = strongly disagree to 5 = strongly agree). Each student's attitude score is the sum of the eight items (range 8–40). Table 7 presents the mean attitude scores. To assess whether attitudes changed over time and differed between groups, independent and paired samples t-tests were also conducted.

Table 8: Mean attitude scores (0–40)

Group	n	Pre-intervention mean ± SD	Post-intervention mean ± SD
Experimental	29	24.41 ± 3.59	32.86 ± 2.61
Control	51	23.51 ± 3.93	32.45 ± 1.78

Source: Field Data (2025).

Attitude scores increased for both groups (~23.5 → 32.9), indicating that students' perceptions of learning geometry improved over the course of the study. However, the difference in post-intervention attitudes between the experimental and control groups was not significant ($t = 0.753$, $p = 0.4555$).

Table 9: Independent samples t-test analysis of post-intervention attitude scores

Groups	N	d. f	Mean	SD	t-value	P-value
Experimental	29	43.0	32.86	2.61	0.75	0.4555
Control	51	43.0	32.45	1.78		

Source: Field Data (2025).

The independent samples t-test compared the post-intervention attitude means of the experimental and control groups. The difference was not statistically significant ($p > 0.05$).

Table 10: Paired samples t-test analysis of pre- and post-intervention attitude scores in the Experimental Group

Test (Expntl group)	N	d. f	Mean	SD	t-value	P-value
Pre-test	29	28	24.41	3.59	9.82	0.000
Post-test	29	28	32.86	2.61		

Source: Field Data (2025).

A paired samples t-test was conducted to examine the difference in attitude scores before and after the intervention in the experimental group. The results showed a significant increase in mean scores from the pre-test mean of 24.41 (SD = 3.59) to the post-test mean of 32.86 (SD = 2.61) among the 29 participants. The t-test value was 9.82 with 28 degrees of freedom, and the p-value was 0.000, indicating that the increase in scores was statistically significant. This suggests that the intervention had a positive and meaningful effect on the attitudes of participants in the experimental group.

Table 11: Paired samples t-test analysis of pre- and post-intervention attitude scores in the Control group

Test (Control group)	N	d. f	Mean	SD	t-value	P-value
Pre-test	51	50	23.51	3.93	14.75	0.000
Post-test	51	50	32.45	1.78		

Source: Field Data (2025).

Both the experimental and control groups exhibited large increases in their attitude scores from pre- to post-intervention, and these changes were highly significant ($p < 0.001$) as shown in Tables 12 and 13. Nonetheless, the difference between the experimental and control groups' post-intervention attitude scores remained non-significant (Table 11), indicating that positive attitudes toward geometry improved generally over time rather than because of the intervention alone.

Detailed response distributions for each attitude statement are presented in Table 11 (experimental group) and Table 12 (control group). The tables show the number and percentage of students selecting each response category.

Table 12: Student attitudes toward Tinkercad – Experimental Group (n = 29)

Statement	SA (n, %)	A (n, %)	N (n, %)	D (n, %)	SD (n, %)
Enjoy geometry with Tinkercad	10 (34.5%)	10 (34.5%)	9 (31.0%)	0 (0.0%)	0 (0)
Lessons more interesting	11 (37.9%)	12 (41.4%)	6 (20.7%)	0 (0.0%)	0 (0)
Better understanding	10 (34.5%)	11 (37.9%)	8 (27.6%)	0 (0.0%)	0 (0)
Easy to use	13 (44.8%)	10 (34.5%)	6 (20.7%)	0 (0.0%)	0 (0)
Visualise shapes	9 (31.0%)	10 (34.5%)	10 (34.5%)	0 (0.0%)	0 (0)
More confident	17 (58.6%)	5 (17.2%)	7 (24.1%)	0 (0.0%)	0 (0)
Use in other topics	10 (34.5%)	12 (41.4%)	7 (24.1%)	0 (0.0%)	0 (0)
Include regularly	10 (34.5%)	7 (24.1%)	12 (41.4%)	0 (0.0%)	0 (0)

Source: Field Data (2025).

Table 12 Continued

Statement	SA (n, %)	A (n, %)	N (n, %)	D (n, %)	SD (n, %)
Enjoy geometry with Tinkercad	20 (39.2%)	18 (35.3%)	13 (25.5%)	0 (0)	0 (0)
Lessons more interesting	16 (31.4%)	20 (39.2%)	15 (29.4%)	0 (0)	0 (0)
Better understanding	17 (33.3%)	14 (27.5%)	20 (39.2%)	0 (0)	0 (0)
Easy to use	16 (31.4%)	19 (37.3%)	16 (31.4%)	0 (0)	0 (0)
Visualise shapes	20 (39.2%)	21 (41.2%)	10 (19.6%)	0 (0)	0 (0)
More confident	17 (33.3%)	19 (37.3%)	15 (29.4%)	0 (0)	0 (0)
Use in other topics	20 (39.2%)	15 (29.4%)	16 (31.4%)	0 (0)	0 (0)
Include regularly	20 (39.2%)	13 (25.5%)	18 (35.3%)	0 (0)	0 (0)

Source: Field Data (2025).

The categories SA, A, N, D and SD in Tables 11 and 12 correspond to Strongly Agree, Agree, Neutral, Disagree and Strongly Disagree, respectively.

Frequency of Questionnaire Responses

Students also provided open-ended feedback about their experiences with Tinkercad. Across the entire sample (n = 80), the most frequently reported positive aspect was that Tinkercad “helps me understand shapes” (27 responses), followed by “it is interactive” (20), “makes learning easier” (17) and “fun and engaging” (16). Challenges included “difficult to use at first” (21 responses), “no challenges” (21), “internet issues” (20) and “slow computers” (18). The most common suggestion was “teacher guidance” (25 responses), followed by “better internet” (21), “more practice time” (20) and “more 3D examples” (14).

In the post-test questionnaire the pattern shifted slightly: the most valued feature was “it is interactive” (24 responses) and the most common suggestion was “more practice time”.

Table 13 Summary of t-test results

Test	Groups	N	t-value	d. f	P-value	Interpretation
Pre vs Post scores (paired) – Experimental	Experimental group pre vs post	29	-0.519	28	0.608	Not significant; no improvement
Pre vs Post scores (paired) – Control	Control group pre vs post	51	-4.285	50	0.0001	Significant improvement
Post scores between groups (independent)	Experimental vs Control	29 & 51	-2.002	62.0	0.0496	Significant difference; control > experimental
Post scores – Gender difference (Experimental)	Experimental group: Male vs Female	13 & 16	-0.655	26.7	0.518	Not significant
Post scores – Gender difference (Control)	Control group: Male vs Female	27 & 24	1.39	48.9	0.172	Not significant

Test	Groups	N	t-value	d. f	P-value	Interpretation
Post attitudes between groups (independent)	Experimental vs Control	29 & 51	0.753	43.0	0.4555	Not significant
Pre vs Post attitude scores (paired) – Experimental	Experimental group: Attitude pre vs post	29	9.818	28	< 0.001	Significant increase
Pre vs Post attitude scores (paired) – Control	Control group: Attitude pre vs post	51	14.751	50	< 0.001	Significant increase

Source: Field Data (2025).

The t-test results in Table 13 provide a comparison of pre- and post-intervention scores across different groups. For the experimental group, the difference between pre- and post-test scores was not statistically significant ($t = -0.519$, $p = 0.608$), suggesting no improvement in test performance. In contrast, the control group showed a significant improvement ($t = -4.285$, $p = 0.0001$) from pre- to post-test. When comparing post-test scores between the two groups, the control group performed significantly better than the experimental group ($t = -2.002$, $p = 0.0496$). Gender differences in post-test scores within each group were not significant. In terms of attitude scores, both the experimental and control groups showed significant increases from pre- to post-intervention (experimental: $t = 9.818$, $p < 0.001$; control: $t = 14.751$, $p < 0.001$). However, there was no significant

difference in post-intervention attitude scores between the two groups ($t = 0.753$, $p = 0.4555$), indicating that both groups benefited similarly in terms of attitude, despite differences in test performance.

4.3 Discussions

The results obtained from the analysis of the data collected in the study are discussed in this section. The discussions were guided by the research questions.

Research question one: What is the effect of Tinkercad on Students' Performance?

The results of this study indicate that the use of Tinkercad as an instructional tool did not lead to a statistically significant improvement in student performance within the experimental group. While there was a slight increase in mean scores from 1.45 (SD = 0.83) to 1.59 (SD = 0.95), the paired samples t-test showed this change was not statistically significant ($t(28) = -0.519$, $p = 0.608$). In contrast, the control group, which did not use Tinkercad, demonstrated a significant performance improvement, increasing from 1.20 to 2.04 ($t(50) = -4.285$, $p = 0.0001$). Furthermore, the independent samples t-test confirmed that the control group outperformed the experimental group on the post-test ($p = 0.0496$).

These findings diverge from several previous studies that have highlighted the positive impact of Tinkercad and similar digital simulation tools on student learning in STEM education. For example, Ali et al. (2021) reported that students who used Tinkercad to simulate circuits demonstrated significantly better conceptual understanding and problem-solving skills than those taught through traditional methods. Likewise, Ramirez and Sanchez (2020) found that integrating Tinkercad into electronics instruction enhanced

engagement and improved test performance, particularly among visual and kinesthetic learners.

However, the current results suggest that simply integrating Tinkercad into instruction may not guarantee improved performance. This aligns with findings by Yildiz and Kara (2019), who emphasized that the effectiveness of digital tools like Tinkercad depends heavily on factors such as instructional design, the duration of the intervention, student familiarity with technology, and the teacher's ability to guide exploratory learning. In their study, students showed minimal performance gains when Tinkercad was used without sufficient scaffolding or alignment with assessment goals.

Moreover, it is possible that the novelty of Tinkercad introduced a cognitive load that interfered with performance, especially if students had limited prior experience with 3D simulation environments. As Sweller's Cognitive Load Theory suggests, unfamiliar interfaces can overwhelm working memory, reducing the effectiveness of learning, even with potentially beneficial tools. This might help explain why the control group, despite using more traditional methods, performed better in this study.

In summary, while Tinkercad has been shown in other studies to enhance student engagement and learning, the current findings suggest that, in this context, it did not lead to a statistically significant improvement in academic performance. The results highlight the importance of contextual factors, including implementation strategies, training, and student readiness, in determining the success of educational technologies.

Research question two: What are the gender differences in students' performance when taught geometry using Tinkercad?

The findings of this study suggest that gender did not play a significant role in determining students' performance in geometry when taught using Tinkercad. Among the experimental group, female students had a slightly higher mean post-test score ($M = 1.69$, $SD = 1.08$) compared to male students ($M = 1.46$, $SD = 0.78$), but the difference was not statistically significant ($t = -0.655$, $p = 0.518$). Similarly, in the control group, male students outperformed females on average (2.22 vs. 1.83), yet this difference was also not statistically significant ($t \approx 1.39$, $p = 0.172$). These results indicate that gender did not significantly moderate the impact of instruction, whether traditional or through Tinkercad, on student performance in geometry.

These results are consistent with a growing body of literature that finds no consistent gender gap in performance when digital tools or visual learning technologies are used in STEM education. For example, Sullivan et al. (2018) found that both male and female students performed equally well in mathematics when using interactive simulation tools, noting that gender differences in learning outcomes tended to diminish in environments that supported exploratory and hands-on learning. Similarly, Lin and Tsai (2020) reported no significant gender differences in performance among students using 3D modeling tools like Tinkercad, though they did note some differences in learning preferences and interaction styles.

Conversely, some earlier studies have reported gender disparities in STEM learning environments, especially in relation to technology usage. For instance, Shapka and Ferrari (2003) suggested that male students were often more confident in using technology, which

could affect engagement levels and performance. However, more recent research, such as that by Tobias and Duffy (2021), emphasizes that with proper scaffolding, training, and equitable access, technological interventions can neutralize gender-based performance gaps, a conclusion that supports the findings of the current study.

Importantly, the lack of significant gender differences in this study may also reflect the inclusive nature of Tinkercad as a learning tool. Its intuitive interface and visual feedback may help create a level playing field by minimizing the need for prior technical experience, which has historically been a barrier for some female students in STEM fields.

Overall, the results of this study align with contemporary research suggesting that when well-designed digital tools like Tinkercad are integrated into the classroom, gender does not significantly influence performance outcomes. This reinforces the importance of inclusive, accessible educational technology that supports learning for all students, regardless of gender.

Research Question 3: What are students' attitudes toward learning geometry using Tinkercad?

The study found that students' attitudes toward learning geometry improved significantly over the course of the intervention for both the experimental and control groups. While the paired samples t-test revealed a significant increase in attitude scores within the experimental group—from a pre-test mean of 24.41 to a post-test mean of 32.86 ($t = 9.82$, $p = 0.000$)—the difference in post-intervention attitudes between the experimental and control groups was not statistically significant. This suggests that the positive change in

attitudes toward geometry was likely influenced by factors common to both groups rather than the Tinkercad intervention alone.

These findings align with prior research emphasizing that exposure to engaging and interactive learning environments tends to enhance student attitudes toward challenging subjects like geometry. For instance, Çakır and Simsek (2019) found that interactive digital tools generally increase motivation and positive perceptions of math learning, regardless of the specific technology used. Similarly, Huang et al. (2021) noted that attitudes improve with increased engagement and active learning opportunities, which can occur through various instructional methods.

Students' qualitative feedback highlights both the strengths and challenges of using Tinkercad. The most frequently cited benefits were its interactivity, ease of understanding shapes, and engaging nature. This is consistent with findings from Miller and Singh (2020), who reported that students appreciate 3D modeling tools for making abstract geometric concepts more tangible and easier to grasp. However, challenges such as initial difficulty in use, technical issues (e.g., slow computers, internet problems), and the need for more teacher guidance were also common. These issues echo concerns raised by Johnson and Davies (2018), who emphasized that without sufficient scaffolding and technical support, even well-designed educational technologies may frustrate learners and limit their effectiveness.

The shift in post-test feedback, with "it is interactive" becoming the most valued feature and "more practice time" the top suggestion, indicates that students recognized the value of Tinkercad's engagement features but desired additional opportunities to develop proficiency. This aligns with Kurt and Yilmaz (2022), who found that repeated practice and

extended exposure are crucial for students to fully benefit from digital learning tools, especially those involving spatial reasoning.

Overall, the findings suggest that while Tinkercad can foster positive attitudes toward geometry by making learning more interactive and enjoyable, its full potential depends on addressing technical challenges and providing adequate instructional support. This supports the broader literature highlighting the importance of combining technology with effective pedagogy to enhance both attitudes and learning outcomes.



CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.0 Overview

This chapter presents a summary of the key findings, draws conclusions from the results, and provides recommendations based on the study. It also offers suggestions for further research. The chapter reflects on the impact of using Tinkercad in teaching geometry, compares it to traditional methods, and considers the role of gender in students' performance and attitudes. The aim is to provide insights for educators and researchers to improve teaching practices and guide future studies.

5.1 Summary of Findings

The study involved 80 students, equally split by gender, who were assigned to either an experimental group using Tinkercad for learning geometry or a control group taught through traditional methods. Analysis of performance showed that the control group experienced a significant improvement in their post-test scores compared to their pre-test scores, with the mean increasing from 1.20 to 2.04 ($p = 0.0001$). In contrast, the experimental group's scores increased only slightly from 1.45 to 1.59, a change that was not statistically significant ($p = 0.608$). When comparing the two groups, the control group outperformed the experimental group significantly on the post-test ($p = 0.0496$),

suggesting that traditional teaching methods were more effective in improving students' performance in this study.

Regarding gender differences, no statistically significant variation was observed in post-test scores between male and female students within either the experimental or control groups. This indicates that gender did not have a moderating effect on student achievement or the impact of the instructional methods used.

In terms of attitudes toward learning geometry, both groups exhibited a significant positive shift following the intervention. Attitude scores increased substantially from pre- to post-intervention in both the experimental and control groups ($p < 0.001$). However, no significant difference in post-intervention attitude scores was found between the groups, implying that the improvement in attitudes was a general trend rather than a specific outcome of using Tinkercad. Qualitative feedback from students highlighted the interactive and engaging features of Tinkercad, although some students noted initial difficulties with the software and technical challenges such as internet connectivity and slow computers.

Overall, while Tinkercad did not significantly enhance students' test performance compared to traditional teaching, it contributed positively to students' attitudes toward learning geometry. Gender was not a significant factor influencing either academic performance or attitude in this context.

5.2 Conclusion

This study set out to examine the effect of using Tinkercad as an instructional tool on students' performance and attitudes toward learning geometry, as well as to explore potential gender differences in these outcomes. The results revealed that while the

traditional teaching method led to a statistically significant improvement in students' performance, the use of Tinkercad did not produce a significant increase in test scores. Despite this, both instructional approaches contributed to a notable positive shift in students' attitudes toward geometry, indicating that students generally developed a more favorable perception of the subject regardless of the teaching method.

Furthermore, gender did not emerge as a significant factor affecting students' academic achievement or attitudes in either the experimental or control groups. This suggests that the impact of the instructional approaches was consistent across male and female students.

In summary, although Tinkercad did not enhance measurable academic performance in this study, it played a valuable role in improving students' engagement and attitude toward learning geometry. These findings highlight the potential of integrating interactive digital tools like Tinkercad to foster positive learning experiences, even if immediate performance gains are not evident. Future research could explore how to optimize the use of such tools and address challenges identified by students to maximize both learning outcomes and engagement.

5.3 Recommendations

Based on the findings of this study, several recommendations are proposed for educators, school administrators, and future researchers. Firstly, while Tinkercad did not significantly improve students' test performance, it had a clear positive effect on their attitudes toward learning geometry. Therefore, educators are encouraged to incorporate Tinkercad and similar interactive tools into geometry lessons as a means to enhance student engagement, interest, and confidence in the subject. However, to maximize the benefits of such tools, it

is recommended that adequate teacher training be provided. Teachers should receive guidance on how to effectively integrate Tinkercad into instructional planning and delivery to ensure that it complements conceptual understanding and reinforces academic achievement.

Additionally, since technical issues such as slow computers and internet connectivity were identified as challenges, schools should invest in improving their technological infrastructure. Ensuring reliable access to digital tools will help minimize frustration and support smoother implementation.

Further research is recommended to explore the long-term impact of Tinkercad on students' performance, particularly with a larger and more diverse sample. Future studies should also investigate how different instructional strategies can be blended with Tinkercad to produce stronger academic outcomes. Lastly, it may be useful to conduct follow-up studies focused on students who initially struggle with the tool to determine the support needed to improve their learning experience and outcomes.

5.4 Suggestions for Further Studies

Although this study provided valuable insights into the impact of Tinkercad on students' performance and attitudes toward learning geometry, several areas remain open for further exploration. Firstly, future studies should consider using a larger and more diverse sample size, including students from different schools, regions, or educational levels. This would enhance the generalizability of the findings and provide a broader perspective on the effectiveness of Tinkercad in varying learning contexts.

Secondly, it is recommended that future research adopt a longitudinal approach to examine the long-term effects of Tinkercad on student learning. A short-term intervention may not fully capture the potential benefits of sustained use of digital tools in mathematics instruction. Tracking students' progress over an extended period could reveal deeper learning gains or evolving attitudes that were not evident in this study.

Moreover, further studies could explore the combined use of Tinkercad with other instructional strategies, such as collaborative learning, project-based learning, or flipped classrooms, to determine whether a blended approach yields better academic outcomes. Investigating the instructional design and pedagogical methods that best support the use of Tinkercad would also be beneficial.

Additionally, given the technical challenges faced by some students, such as poor internet connectivity and limited access to functional devices, future research should examine how infrastructural support and teacher facilitation affect the successful integration of digital tools in the classroom.

Finally, it may be valuable to conduct qualitative studies that focus on students' and teachers' experiences with Tinkercad in more depth. Interviews, classroom observations, and case studies could uncover important insights into how digital tools influence engagement, understanding, and classroom dynamics in ways that standardized tests may not fully capture.

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APPENDICES

APPENDIX A

DATA COLLECTION INSTRUMENTS

Section I: Demographic Information

Gender: Male [] Female []

Age: Below 14 years [] 15-17 years [] 18-20 [] Above 20 years []

Section II: Geometry Achievement Test (Pretest/Posttest)

Instructions: Answer all questions. For multiple-choice questions, circle the correct letter. For short-answer questions, write your answer clearly in the space provided.

PART A: MULTIPLE CHOICE (Circle the correct option)

1. Which of the following shapes has exactly one pair of parallel sides?

- A. Square
- B. Rectangle
- C. Trapezium
- D. Rhombus

2. Which shape has all sides equal and all angles equal?

- A. Rectangle
- B. Parallelogram
- C. Square
- D. Rhomboid

3. What is the sum of the interior angles of a triangle?

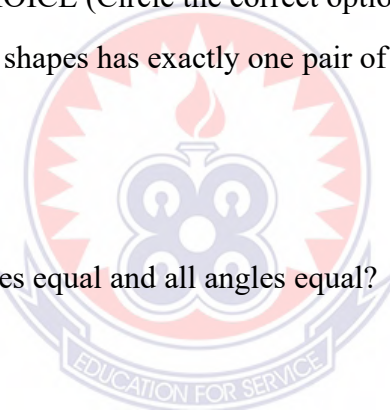
- A. 180°
- B. 90°
- C. 360°
- D. 270°

4. What is the volume of a cube with side length 5cm?

- A. 10cm^3
- B. 15cm^3
- C. 125cm^3
- D. 100cm^3

5. Which transformation flips a shape over a line?

- A. Translation
- B. Rotation



- C. Reflection
- D. Enlargement

PART B: SHORT ANSWERS (Show all workings)

6. A rectangular prism has a length of 8cm, width of 4cm, and height of 3cm. Calculate its volume.

.....
 .

7. Draw and label a cube. Indicate at least 3 faces and 3 edges.

.....
 .

8. Using a ruler and compass only, construct an equilateral triangle of side 5cm.

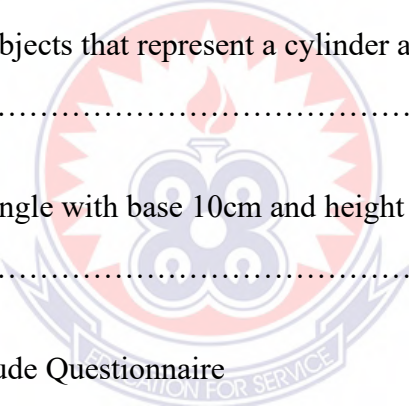
.....
 .

9. Identify two real-life objects that represent a cylinder and a sphere respectively.

.....
 .

10. Find the area of a triangle with base 10cm and height 6cm.

.....
 .



Section III: Student Attitude Questionnaire

Instructions: Tick (✓) the box that best describes your opinion for each of the following statements.

Scale: 1 = Strongly Disagree | 2 = Disagree | 3 = Neutral | 4 = Agree | 5 = Strongly Agree

Statement	1	2	3	4	5
1. I enjoy learning geometry more when using Tinkercad.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2. Tinkercad makes geometry	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

lessons
more
interesting
and
engaging.

3. I
understand
geometric
concepts
better when
using
Tinkercad.

4. I find
Tinkercad
easy to use
during
mathematics
lessons.

5. Tinkercad
helps me
visualize
shapes
better than
the
textbook.



6. I am
more
confident in
geometry
after using
Tinkercad.

7. I would
prefer to use
Tinkercad in
other math
topics as
well.

8. Tinkercad
should be
included

regularly in
mathematics
lessons.

PART B: Open-Ended Questions

What do you like most about learning geometry with Tinkercad?

.....
.

What challenges did you face when using Tinkercad in learning geometry?

.....
.

Suggest one way your teacher could improve the use of Tinkercad in class.

.....
.

