

Teachers' Use of Graphical Methods in Teaching Coordinate Geometry in Zambian Secondary Schools: A Case Study in Some Selected Schools of Chongwe District in Lusaka Province

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Abstract- The study investigated the use of graphical methods by teachers when teaching coordinate geometry in Zambian secondary school to be specific in Chainda, Chalimbana and Chongwe secondary schools in Chongwe district Lusaka province. Coordinate geometry is an important topic in mathematics that connects algebra and geometry through graphical representations. However, many learners experience difficulties in understanding the topic due to abstract teaching approaches. The study examined how teachers apply graphical techniques, the challenges they encounter, and the effects of graphical methods on learners' understanding. A descriptive research design was used. Data were collected from mathematics teachers and learners through questionnaires, interviews and classroom observations. Findings reveal that graphical methods improve learners' conceptual understanding, engagement, and performance in coordinate geometry. However, limited teaching resources, insufficient teacher training and time constraints hinder effective use of graphical approaches. The study recommends increased teacher training, provision of teaching aids and integration of digital tools such as GeoGebra to enhance the teaching of coordinate geometry.

I. INTRODUCTION

Mathematics is widely regarded as one of the most important subjects in the school curriculum because it develops logical thinking, problem-solving skills, and analytical reasoning among learners. According to United Nations Educational, Scientific and Cultural Organization, mathematics plays a critical role in scientific and technological development and contributes significantly to national development (UNESCO, 2015). In secondary schools, coordinate geometry is an essential topic because it links algebra and geometry while helping learners visualize mathematical relationships.

Coordinate geometry involves representing algebraic equations graphically on the Cartesian plane to understand relationships between variables. Graphical methods are therefore important instructional strategies used by teachers to help learners visualize mathematical concepts such as gradients, intercepts, distance between points, and equations of straight lines. According to George Pólya, effective mathematics teaching requires the use of visual representations that help learners understand abstract mathematical ideas (Pólya, 1957).

Graphical methods used are essential in teaching coordinate geometry because they help learners visualize mathematical

relationships. Graphs allow learners to understand concepts such as gradients, intercepts, distance between points and equations of lines. Research shows that graphical relations help learners understand mathematical relationships better than purely symbolic representations.

In many education systems, graphical methods are widely used to improve conceptual understanding in mathematics. Visual representation of mathematical ideas allows learners to see relationships and patterns that may not be easily understood through symbolic manipulation alone. Richard Skemp argues that mathematics learning becomes meaningful when learners develop relational understanding rather than merely memorizing procedures (Skemp, 1976).

In the context of Zambia, the mathematics curriculum for secondary schools emphasizes the use of graphical approaches in teaching topics such as linear equations, quadratic functions, and coordinates geometry. The curriculum developed by Curriculum Development Centre encourages teachers to use learner-centered approaches including diagrams, graphs, and practical activities to enhance conceptual understanding (CDC, 2013).

Despite the recognized importance of graphical methods in mathematics instruction, many learners still experience difficulties in understanding coordinate geometry concepts. Poor performance in mathematics examinations has been observed in several secondary schools

across Zambia. Reports from the Examinations Council of Zambia indicate that learners often struggle with graphical interpretation and construction of coordinate graphs in national examinations (ECZ, 2021).

Research in mathematics education suggests that the methods used by teachers significantly influence learners' understanding of mathematical concepts. Jerome Bruner emphasized that effective teaching should involve multiple forms of representation including visual, symbolic, and concrete forms of learning (Bruner, 1966). When graphical methods are properly used, learners are able to visualize relationships between variables and better understand coordinate geometry concepts.

However, some teachers may rely heavily on traditional lecture methods without fully utilizing graphical approaches in their teaching. Limited teaching resources, inadequate training, and large class sizes may also affect teachers' ability to effectively implement graphical teaching methods.

Therefore, this study seeks to investigate teachers' use of graphical methods in teaching coordinate geometry in Zambian secondary schools. The study aims to examine how teachers apply graphical approaches during instruction, identify challenges they face, and explore strategies that may improve the teaching and learning of coordinate geometry.

1.1 Background of the Study

Mathematics education plays an important role in developing learners' analytical thinking and problem-solving abilities. According to Organization for Economic Co-operation and Development, strong mathematical skills are essential for participation in modern societies and knowledge-based economies (OECD, 2018). Among the various topics taught in secondary school mathematics, coordinate geometry is particularly important because it connects algebraic expressions with geometric representation

. Coordinate geometry, also known as analytic geometry, represents a fundamental branch of mathematics that combines algebraic methods with geometric concepts. The Cartesian coordinate system, developed by René Descartes in the seventeenth century, revolutionized mathematics by providing a systematic method for representing geometric figures through algebraic equations and, conversely, interpreting algebraic relationships through geometric visualization. This dual

representation capability makes coordinate geometry uniquely powerful in mathematical reasoning and problem-solving. In secondary education, coordinate geometry serves multiple pedagogical purposes. First, it reinforces and extends learners' understanding of algebraic concepts such as variables,

equations, and functions by providing visual representations that make abstract ideas concrete. Second, it develops spatial reasoning abilities essential for success in advanced mathematics, science, and technical fields. Third, it provides practical tools for solving real-world problems involving distance, midpoint, gradient, and area calculations. Fourth, it lays the groundwork for calculus, linear algebra, and other advanced mathematical disciplines that learners may encounter in tertiary education.

The Zambian secondary school mathematics curriculum recognizes the importance of coordinate geometry by incorporating it at both junior and senior secondary levels. At the junior secondary level (Grades 8-9), learners are introduced to basic concepts including the Cartesian plane, plotting points, reading coordinates, and simple graphs. At the senior secondary level (Grades 10-12), the curriculum expands to include more complex topics such as distance formula, midpoint formula, gradient of a line, equation of a straight line, parallel and perpendicular lines, and applications of coordinate geometry to geometric problems.

Mathematics also serves as the backbone of scientific and technological advancement, yet many students in Zambia struggle with abstract concepts. Coordinate geometry is a critical bridge between algebra and geometry, but it often becomes a hurdle when students fail to visualize the relationships between equations and their spatial representations.

In many Zambian secondary schools, the teaching of mathematics has traditionally leaned toward rote memorization and algebraic manipulation. While the Zambian education curriculum framework emphasizes learner-centered approaches, the transition to visual mastery remains a challenge. Graphical methods using coordinated planes, sketches and plotting are essential tools that transform abstract variables into tangible shapes and lines, making the logic of geometry more intuitive.

However, several factors may hinder the effective use of these methods. These include a lack of teaching aids like graph boards, limited access to digital tools like Geogebra, and the pressure to complete a heavy syllabus, which often leads teachers to prioritize shortcuts over deep conceptual understanding. Understanding how to improve currently navigate these tools is vital to improving student performance in national examinations like ECZ Grade 12 exams. Coordinate

geometry was first developed by René Descartes in the seventeenth century. The Cartesian coordinate system introduced by Descartes allows mathematical relationships to be represented graphically on a plane. This innovation made it possible to analyze geometric shapes using algebraic equations and graphical representations.

In the classroom context, graphical methods involve plotting points, drawing graphs, and interpreting relationships between variables using the Cartesian plane. These methods help learners visualize mathematical ideas and develop deeper conceptual understanding.

In the context of Chongwe district, the effective use of these methods is often influenced by localized challenges. These include the availability of basic mathematical instruments and graph paper, the high teacher to pupil ratios in growing community schools and varying levels of teacher proficiency in integrating visual pedagogy.

Furthermore, as the district begins to embrace digital literacy, the gap between traditional chalkboard sketching and use of ICT-based graphing tools creates unique instructional landscape. Investigating how teachers in this specific district utilize graphical methods is crucial for identifying the pedagogical gaps that hinder student conceptual clarity in coordinate geometry.

Educational researchers have long emphasized the importance of visual learning in mathematics. According to Jean Piaget, learners construct knowledge through active interaction with their environment, and visual representations play an important role in cognitive development (Piaget, 1972). Graphs and diagrams therefore support learners in developing mental models of mathematical relationships.

Similarly, Lev Vygotsky argued that learning occurs through social interaction and the use of tools and representations that support cognitive development (Vygotsky, 1978). Graphical representations in mathematics act as cognitive tools that help learners interpret complex information.

In Zambia, mathematics is a compulsory subject at secondary school level and is considered essential for science-related careers. The national curriculum encourages the use of learner-centered teaching approaches to enhance understanding. However, despite these efforts, performance in mathematics remains a concern in many schools.

Reports from the Ministry of Education Zambia indicate that learners often face difficulties in topics that require graphical interpretation such as coordinate geometry and functions (MoE, 2019). These challenges may be linked to teaching approaches used in the classroom.

Several studies have shown that effective use of graphical methods improves learners' understanding of mathematical relationships. According to Hiebert and Carpenter (1992), graphical representation helps learners connect mathematical symbols with real-world interpretations. When teachers actively involve learners in graph construction and interpretation, learners are more likely to develop conceptual understanding.

However, the extent to which teachers use graphical methods in teaching coordinate geometry in Zambian secondary schools is not well documented. This study therefore aims to explore teachers' practices and experiences in using graphical approaches in the classroom.

Chongwe District is located in Lusaka Province, approximately 45 kilometers east of Zambia's capital city. The district encompasses a mix of urban, peri-urban, and rural settlements, with economic activities ranging from formal employment in government and service industries to small-scale farming and trading. This diversity is reflected in the learner populations attending secondary schools within the district, which come from varied socioeconomic backgrounds and bring different levels of educational preparation to their mathematics studies. Chainda Secondary School, Chalimbana Secondary School, and Chongwe Secondary School serve as important educational institutions within the district. These schools admit learners from surrounding communities and are expected to deliver the national mathematics curriculum, including coordinate geometry content, to their students. Like schools elsewhere in Zambia, they operate within resource constraints that may affect the quality of mathematics instruction they can provide. The choice of these three schools as study sites is deliberate and strategic. Chainda Secondary School, located in a peri-urban area, serves a diverse population including learners from both formally employed families and those engaged in informal economic activities. Chalimbana Secondary School, situated near the Chalimbana River and close to the Chalimbana University School of Education field station, has historical connections to teacher education and may benefit from proximity to academic resources. Chongwe Secondary School, located in the district administrative center, serves as the main secondary institution for the town and surrounding areas. Together, these three schools provide a representative picture of secondary mathematics education in the district, capturing variations in location, resources, and learner demographics that characterize the broader educational landscape.

Teachers occupy a central position in determining whether and how graphical methods are employed in coordinate geometry instruction. Their content knowledge, pedagogical skills, beliefs about teaching and learning, and access to resources all influence their instructional decisions and practices. Understanding teachers' current use of graphical methods

requires examining multiple dimensions of their professional practice.

Content knowledge for teaching coordinate geometry encompasses understanding of coordinate geometry concepts themselves, knowledge of how these concepts connect to other mathematical topics, and awareness of common learner misconceptions and difficulties.

Teachers need to know not only how to plot points and determine equations but also why these procedures work and how to explain them to learners in accessible ways.

1.2 Statement of the Problem

Despite the importance of coordinate geometry in the secondary school mathematics curriculum, many learners in Zambia continue to perform poorly in this topic. Examination reports from the Examinations Council of Zambia indicate that learners often struggle with graph construction, interpretation of coordinates, and understanding relationships between algebraic equations and graphical representations (ECZ, 2021). One possible factor contributing to this problem is the teaching methods used by teachers during instruction. Although graphical methods are recommended for teaching coordinate geometry, some teachers may not fully utilize them in their lessons. Instead, they may rely heavily on theoretical explanations without involving learners in graphical activities. Limited teaching resources, inadequate training, and time constraints may also influence teachers' use of graphical teaching strategies. As a result, learners may fail to develop the visual and conceptual understanding necessary for mastering coordinate geometry.

Therefore, this study seeks to investigate how teachers use graphical methods in teaching coordinate geometry in Zambian secondary schools and to identify challenges that affect effective implementation of these methods.

The teaching and learning of coordinate geometry at secondary school level presents persistent challenges that have implications for learners' mathematical development and their subsequent academic and career opportunities. Coordinate geometry requires learners to integrate algebraic manipulation with geometric visualization, a cognitive demand that many students find difficult to meet. When instruction fails to adequately address these challenges, learners may develop superficial understanding, rely on rote memorization without conceptual grasp, and ultimately underperform in assessments that require application of coordinate geometry knowledge.

Graphical methods offer potential solutions to these challenges by making abstract coordinate geometry concepts visible and tangible. Through graphs, diagrams, and constructions, learners can see mathematical relationships rather than simply

manipulating symbols according to prescribed rules. Research from various educational contexts has demonstrated that effective use of graphical methods can enhance learner understanding, engagement, and achievement in coordinate geometry and related topics (Mashingaidze, 2012; Tatar, 2010).

However, the extent to which teachers in Zambian secondary schools actually employ graphical methods in their coordinate geometry instruction remains largely unknown. While policy documents advocate for learner-centred, visually-rich mathematics teaching, and while teacher education programmes presumably prepare teachers to use such methods, systematic evidence about classroom practices is lacking. This knowledge gap is particularly pronounced at the local level, including in Chongwe district where Chainda, Chalimbana, and Chongwe Secondary Schools operate.

The absence of such evidence has practical consequences. Without understanding current practices, it is impossible to identify areas where graphical method instruction is working well and could serve as a model for others, or areas where instruction is falling short and requires intervention. Educational planners cannot make evidence-based decisions about resource allocation for graphing materials and technology. Teacher educators cannot design professional development that addresses actual classroom needs. School administrators cannot provide targeted support to mathematics teachers. And teachers themselves cannot learn from the effective practices of their colleagues.

Furthermore, even basic descriptive information about graphical method instruction in these schools is lacking. Questions about which graphical methods teachers use, how frequently they use them, what challenges they encounter, and what support they need remain unanswered. This lack of information perpetuates a cycle where problems remain unidentified and therefore unaddressed, potentially compromising the quality of mathematics education that learners receive.

The problem this study addresses, therefore, is the insufficient understanding of teachers' use of graphical methods in teaching coordinate geometry at Chainda, Chalimbana, and Chongwe Secondary Schools. This lack of understanding impedes efforts to improve mathematics instruction and learner outcomes in these schools and potentially in similar contexts elsewhere. The study seeks to generate the knowledge needed to inform practice, policy, and further research by providing comprehensive documentation and analysis of current graphical method instruction in coordinate geometry at these three secondary schools.

1.3 Purpose of the Study

The purpose of this study is to examine teachers' use of graphical methods in teaching coordinate geometry in Zambian secondary schools.

The study aims to explore how teachers apply graphical approaches in their teaching, identify challenges they face, and suggest strategies that may improve the effectiveness of teaching coordinate geometry.

The other purpose of this study is to investigate teachers' use of graphical methods in teaching coordinate geometry at Chainda, Chalimbana, and Chongwe Secondary Schools in Chongwe District, Lusaka Province, Zambia. The study aims to achieve this purpose by systematically examining the graphical methods teachers employ, the frequency and contexts of their use, the factors that influence teachers' selection and implementation of graphical methods, the challenges teachers encounter, and the support they require to enhance their graphical method instruction.

This investigation is guided by the recognition that understanding current practices is an essential prerequisite for improvement. By documenting what teachers are currently doing, why they are doing it, and what difficulties they face, the study will establish a baseline against which future developments can be measured and a foundation upon which interventions can be built. The purpose extends beyond mere description to include analysis that reveals patterns, relationships, and implications for practice.

The study also aims to generate findings that are useful to multiple stakeholders. For teachers at the participating schools and elsewhere, the research may provide insights into effective practices and raise awareness of opportunities for enhancing graphical method instruction. For school administrators, the findings may inform decisions about resource allocation, timetabling, and teacher support. For district education officials, the research may identify professional development needs and guide planning for in-service training. For teacher educators, the study may suggest areas where pre-service programmes could be strengthened. For educational researchers, the investigation may generate hypotheses and questions for further inquiry.

Ultimately, the purpose of this study is to contribute to improving the quality of mathematics education in Zambian secondary schools by generating knowledge that can be used to enhance teachers' use of graphical methods in coordinate geometry instruction. While the study is focused on three specific schools, its findings may have relevance for similar contexts elsewhere in Zambia and beyond, particularly in resource-constrained educational settings where teachers face comparable challenges and opportunities.

1.4 Objectives of the Study

The study will be guided by the following objectives:

1. To examine how teachers use graphical methods in teaching coordinate geometry in Zambian secondary schools.
2. To identify challenges teachers face when using graphical methods in teaching coordinate geometry.
3. To suggest strategies that can improve the use of graphical methods in teaching coordinate geometry.

1.5 Research Questions

The study will address the following research questions:

1. How do teachers use graphical methods in teaching coordinate geometry in Zambian secondary schools?
2. What challenges do teachers face when using graphical methods in teaching coordinate geometry?
3. What strategies can improve the use of graphical methods in teaching coordinate geometry?

1.6 Delimitation of the Study

This study will focus on selected secondary schools in Zambia. The research will specifically examine the use of graphical methods in teaching coordinate geometry among mathematics teachers.

The study will only involve mathematics teachers and learners studying coordinate geometry at secondary school level. Other mathematics topics and other educational levels will not be included in the study.

1.7 Limitations of the Study

Limitations refer to potential weaknesses or constraints that may affect the quality, interpretation or applicability of the study's findings. This section acknowledges these limitations transparently, demonstrating the researcher's awareness of factors that could influence the research outcomes.

1.7.1 Sample Size Limitations

The study focuses on three secondary schools in a single district, with mathematics teachers from these schools as participants. While this sample size is appropriate for qualitative research aiming for depth rather than breadth, it limits the extent to which findings can be

generalized to other schools, districts, or contexts. Teachers' practices may vary considerably depending on local circumstances, and the three schools may not represent the full range of variation present in Zambian secondary education.

1.7.2 Social Desirability Bias

As with any research involving self-report through interviews, there is a risk of social desirability bias the tendency for participants to present themselves in ways they perceive as favorable or expected by the researcher. Teachers may

overstate their use of graphical methods or describe their practices in ways that align with idealized notions of teaching rather than actual classroom behavior. The inclusion of classroom observations helps mitigate this limitation by providing direct evidence of practices, but the presence of an observer may itself influence teacher behavior, potentially resulting in performance that differs from typical practice.

1.7.3 Researcher Subjectivity

Qualitative research acknowledges that the researcher is the primary instrument for data collection and analysis, bringing their own perspectives, experiences, and biases to the research process. The researcher's background in mathematics education, familiarity with the Zambian educational context and assumptions about effective teaching may influence how data are collected, interpreted, and reported. Strategies to address this limitation include reflexivity (ongoing self-awareness of potential biases), triangulation (using multiple data sources), and member checking (verifying interpretations with participants).

1.7.4 Resource Constraints

The study is conducted with limited time, funding, and other resources, which may affect the depth and breadth of data collection. Extended observation periods, follow-up interviews, or inclusion of additional schools would require resources beyond those available for this research. Despite these constraints, every effort is made to collect rich, detailed data that adequately address the research questions within the practical limitations of the study.

1.7.5 Cross-Sectional Design

The study employs a cross-sectional design, collecting data at a single point in time rather than tracking changes over an extended period. This design provides a snapshot of current practices but cannot reveal how teachers' use of graphical methods evolves over time,

how practices respond to interventions or changing circumstances, or whether patterns observed during the study period are typical or exceptional. Longitudinal research would be needed to address these temporal dimensions.

1.7.6 Focus on Teacher Practices

By focusing on teacher practices rather than learner outcomes, the study does not directly measure the effectiveness of graphical methods in enhancing learner understanding or achievement. While research from other contexts suggests that graphical methods can be effective, this study does not test that proposition empirically within the specific schools under investigation. Claims about the benefits of graphical methods must therefore be based on existing literature rather than evidence generated by this study.

1.7.7 Language Considerations

Data collection is conducted in English, the official language of instruction in Zambian secondary schools and the language in which teachers are professionally trained. However, for some participants, English may be a second or third language, which could affect their ability to express ideas fully and precisely during interviews. The researcher is attentive to this possibility and uses probing, clarification, and paraphrasing to ensure accurate understanding, but some nuance may inevitably be lost in cross-language communication.

1.8 Significance of the Study

The findings of this study may be beneficial in several ways. This study holds significance for multiple stakeholders and contributes to various domains of educational knowledge and practice. The following sections elaborate the significance of the research for different audiences and purposes.

1.8.1 Contribution to Educational Knowledge

The study contributes to the body of knowledge about mathematics teaching practices in general and graphical method instruction in particular. By documenting and analyzing teachers' use of graphical methods in coordinate geometry at three Zambian secondary schools, the research adds context-specific evidence to the international literature on mathematics education. This contribution is particularly valuable because much existing research originates from developed countries with different educational systems, resources, and challenges.

The study also contributes to understanding how mathematics teachers in resource-constrained contexts adapt their practices to available materials and circumstances. This knowledge is relevant not only for Zambia but for other developing countries facing similar educational challenges. The findings may inform theoretical frameworks about teacher decision-making, pedagogical adaptation, and the relationship between resources and instruction.

1.8.2 Implications for Policy

Educational policymakers at various levels may find this study's findings useful for informing decisions about mathematics education. At the national level, the Ministry of Education may use the research to understand how curriculum intentions translate into classroom practices and to identify areas where policy implementation requires strengthening. At the provincial level, Lusaka Province education officials may gain insights into mathematics teaching in a district within their jurisdiction, informing regional planning and resource allocation. At the district level, Chongwe District education authorities may use the findings to understand the specific needs of schools in their area and to target support accordingly. The study may also inform policy discussions about teacher preparation and professional development. If findings reveal

gaps in teachers' knowledge or skills related to graphical method instruction, this evidence can support arguments for strengthening pre-service programmes or expanding in-service training opportunities. Similarly, if resource constraints emerge as significant barriers to effective instruction, the study may provide evidence for policy advocacy regarding material support for schools.

1.8.3 Implications for Practice

For teachers at the participating schools, the study may provide insights into their own practices and those of their colleagues. Participation in research can stimulate reflection on teaching approaches and consideration of alternatives. When findings are shared with participants, teachers may learn about effective practices used elsewhere and gain ideas for enhancing their own instruction.

For mathematics teachers more broadly, the study may offer examples of how graphical methods can be employed in coordinate geometry teaching, along with analysis of factors that support or hinder such instruction. Teachers facing similar resource constraints may find the experiences of Chainda, Chalimbana, and Chongwe teachers relevant to their own situations.

For school administrators, the findings may inform decisions about resource acquisition, timetabling, and teacher support. If the study identifies specific resource needs that would enhance graphical method instruction, administrators may be better positioned to advocate for and acquire those resources. If the research reveals professional development needs, administrators can incorporate these into school improvement planning.

1.8.4 Implications for Teacher Education

Teacher educators at universities and colleges may use the study's findings to review and strengthen their programmes. If the research identifies gaps in teachers' preparation for graphical method instruction, pre-service programmes can be adjusted to address these gaps. If the study reveals challenges that novice teachers face in implementing graphical methods, teacher educators can prepare students more effectively for these realities.

The study may also inform the design of professional development programmes for practicing teachers. By identifying the specific challenges teachers encounter and the support they require, the research provides guidance for in-service training content and formats. Professional development can be tailored to address actual needs rather than assumed ones.

1.8.5 Implications for Further Research

This study generates findings that may stimulate further research questions and investigations. Researchers interested in mathematics education, teaching methods, or Zambian education may build on this study in various ways. Potential directions for further research include:

- expanding the study to include more schools in Chongwe district or other districts for broader generalization
- investigating learner perspectives on graphical method instruction and its perceived effectiveness
- conducting experimental or quasi-experimental studies to test the effects of specific graphical methods on learner achievement
- examining the relationship between graphical method instruction and learner performance on national examinations
- exploring how teachers develop their knowledge and skills for graphical method instruction over time
- comparing graphical method instruction across different mathematical topics or different subject areas
- investigating the potential of technology-enhanced graphical methods in resource-constrained contexts

1.8.6 Contribution to School Improvement

Finally, the study contributes to school improvement efforts at Chainda, Chalimbana, and Chongwe Secondary Schools specifically. By providing systematic documentation and analysis of current practices, the research establishes a baseline for these schools to assess their mathematics instruction and identify areas for development. The process of participating in research may itself stimulate reflection and dialogue among teachers about their practices. When findings are shared with schools, they may inform school development planning and resource mobilization efforts.

1.9 Theoretical Framework

This study is guided by the Constructivist Learning Theory, which emphasizes that learners actively construct knowledge through experience and interaction.

Constructivism is associated with educational theorists such as Jean Piaget and Lev Vygotsky. According to Piaget (1972), learners build knowledge through cognitive processes that involve interaction with their environment. Graphical representations in mathematics therefore provide learners with visual experiences that support knowledge construction.

Vygotsky (1978) further emphasized the importance of social interaction in learning. He introduced the concept of the Zone of Proximal Development, which suggests that learners can

achieve higher levels of understanding when guided by teachers or peers.

In the context of coordinate geometry, graphical methods serve as tools that support learners in visualizing mathematical relationships. When teachers involve learners in plotting graphs and interpreting graphical information, they create opportunities for active learning and conceptual understanding. Therefore, the constructivist theory provides a strong foundation for understanding how graphical methods can enhance the teaching and learning of coordinate geometry.

1.10 Definition of Key Terms

Coordinate Geometry: A branch of mathematics that studies geometric shapes using algebraic equations on a coordinate plane.

Graphical Methods: Are teaching approaches that involve the use of graphs, diagrams, and visual representations to explain mathematical concepts.

Cartesian Plane: A two-dimensional plane formed by the intersection of the horizontal x-axis and the vertical y-axis used to plot points and graphs.

Secondary School: An educational institution that provides education to learners typically between grades 8 and 12.

Mathematics Teacher: A professional educator responsible for teaching mathematical concepts and skills to learners.

II: LITERATURE REVIEW

This chapter reviews literature related to the use of graphical methods in teaching coordinate geometry. The purpose of the literature review is to examine previous research findings, theoretical perspectives, and scholarly discussions that relate to graphical approaches in mathematics teaching. The chapter discusses the concept of coordinate geometry, graphical teaching methods, the importance of visualization in mathematics learning, teachers' instructional strategies, challenges faced in the use of graphical methods, and empirical studies related to the topic.

A literature review helps identify gaps in existing research and provides a foundation for the current study. According to educational research scholars, reviewing existing literature helps researchers understand how previous studies have approached similar problems and how their findings contribute to knowledge development in a particular field.

The three secondary schools under study—Chainda, Chalimbana, and Chongwe—are located in Chongwe District, Lusaka Province. Recent educational developments in the district provide important context for this research. According to the Chongwe Municipal Council (2025), the Constituency Development Fund (CDF) has played a transformative role in improving education infrastructure in the district, including at Chalimbana and Chongwe Secondary Schools. New classroom blocks have been constructed, decongesting previously overcrowded spaces and creating more conducive learning environments. Additionally, enrolment in Chongwe District schools has surged by 70% over three years, from 68,555 in 2022 to approximately 90,000 in 2025, attributed to Zambia's Free Education Policy and CDF bursaries (TheAgency Media, 2025). These developments have implications for teaching and learning, including how graphical methods are employed in mathematics classrooms.

This literature review draws on a range of sources, including peer-reviewed journal articles, conference papers, theses, and educational reports. The review is structured into six main sections following this introduction: the theoretical framework underpinning the study, the nature and importance of graphical methods in teaching coordinate geometry, teachers' practices in using graphical methods, challenges faced in implementing graphical approaches, strategies for improving graphical method instruction, and a summary synthesizing the literature and identifying gaps that this study addresses.

Coordinate geometry occupies a unique position in secondary school mathematics curricula worldwide, serving as a bridge between algebraic and geometric reasoning. Mashingaidze (2012) notes that coordinate geometry topics, such as geometric transformations,

require learners to have a good grasp of multiple skills, including vectors, construction of shapes, symmetry, properties of shapes, Cartesian equations and graphs, similarity, and congruency. This interdisciplinary nature makes the teaching of coordinate geometry particularly dependent on effective use of graphical representations. The importance of graphical methods in this context cannot be overstated, as they provide learners with visual access to abstract mathematical concepts.

2.1 Concept of Coordinate Geometry

Coordinate geometry, also known as analytic geometry, is a branch of mathematics that studies geometric figures using

algebraic equations and coordinates on a plane. The concept was developed by the French mathematician René Descartes in the seventeenth century. Descartes introduced the Cartesian coordinate system which allows geometric shapes to be represented algebraically and graphically.

The Cartesian plane consists of two perpendicular axes known as the x-axis and the y-axis. These axes divide the plane into four quadrants and allow the plotting of points using ordered pairs. This system enables learners to visualize relationships between algebraic equations and geometric shapes. Coordinate geometry plays an important role in mathematics education because it connects algebraic and geometric concepts. Through graphical representation, learners can understand relationships between variables and interpret mathematical patterns.

Research in mathematics education emphasizes that understanding coordinate geometry requires both algebraic manipulation and graphical interpretation skills. Graphs help learners visualize relationships such as slopes, intercepts, and distances between points. Therefore, graphical methods are essential teaching tools in coordinate geometry lessons.

2.2 Defining Graphical Methods in Mathematics Education

Graphical methods in mathematics education refer to instructional approaches that use visual representations such as graphs, diagrams, charts, and physical models to illustrate mathematical concepts and relationships. In the specific context of coordinate geometry, graphical methods include plotting points on Cartesian planes, drawing geometric figures using coordinates, interpreting graphs of linear and quadratic functions, using technology to generate dynamic visualizations, and employing manipulative such as geoboards to explore geometric properties.

The Media4Math resource collection (2025) provides 34 examples of coordinate systems instruction, each "using clear, annotated diagrams that help students visualize how ordered pairs correspond to positions on the plane. This structured approach builds connections between algebraic reasoning and geometric representation, helping students move fluidly between symbolic and graphical forms". This description captures the essence of graphical methods: they bridge the symbolic and the visual, enabling learners to see mathematical relationships.

2.3 The Role of Graphical Methods in Conceptual Understanding

Graphical methods serve multiple cognitive functions in mathematics learning. First, they externalize abstract concepts, making them accessible to sensory experience. When learners plot points and observe the lines that connect them, they are not merely executing procedures but constructing mental images of mathematical relationships. Second, graphical methods support pattern recognition, allowing learners to identify regularities and generalize from specific instances. Third, they provide a medium for exploration and conjecture, enabling learners to test hypotheses and revise their thinking in response to visual feedback.

Joswick et al. (2026) describe how the slow reveal graph routine "supported mathematical discourse, normalized conjecture and error, and strengthened connections between mathematical representations and students' lived experiences". This routine exemplifies how graphical methods can transform classroom dynamics, positioning students as active sense-makers rather than passive recipients of information.

Mashingaidze (2012) argues that a graphical approach to geometric transformations "may cause understanding and enjoyment amongst teachers and learners". The connection between understanding and enjoyment is significant: when learners grasp concepts through visual means, they experience the satisfaction of insight, which in turn motivates further engagement with mathematics.

2.4 The Uniqueness of Coordinate Geometry as a Graphical Subject

Coordinate geometry is distinctive among mathematics topics in that it explicitly integrates algebraic and geometric thinking. The Cartesian plane itself is a graphical device—a visual representation of the relationship between two variables. Every point on the plane has both geometric significance (its position) and algebraic significance (its coordinates). This dual nature makes coordinate geometry inherently graphical.

However, the graphical nature of coordinate geometry also creates learning challenges. The researcher cited in the CiNii database (2024) observes that students often have limited mental operations for understanding figures with coordinates. They may know the coordinate system as a set of rules but cannot apply this knowledge to interpret or construct figures. This disconnects between procedural knowledge and

conceptual understanding underscores the importance of teaching approaches that make graphical meanings explicit.

The Russian researcher (2024) notes that when solving plan metric problems using the coordinate method, students have many problems, and teachers rarely use the coordinate method. This finding from the Russian context resonates with observations from other educational systems and highlights a paradox: the coordinate method, which is inherently graphical, is often taught without sufficient attention to its graphical foundations.

2.5 The Zambian Context: Curriculum Expectations

In Zambia, coordinate geometry is taught throughout the secondary school mathematics curriculum. At the junior secondary level (Grades 8-9), learners are introduced to the Cartesian plane, plotting points, interpreting graphs, and simple linear equations. At the senior secondary level (Grades 10-12), the curriculum extends to more complex topics including gradient, equation of a straight line, parallel and perpendicular lines, distance between points, midpoint, area of geometric figures using coordinates, and geometric transformations.

The Mathematics 4024 syllabus, which is examined at the Grade 12 level, includes substantial content on coordinate geometry and transformations. Chisenga and Zulu (2021), in their study conducted at Kenneth Kaunda Provincial STEM Secondary School in Chinsali District; note that geometric transformations require learners to have a good grasp of multiple prerequisite skills. The graphical nature of these topics is explicit in the syllabus, which expects learners to perform constructions, draw graphs, and interpret visual representations.

The curriculum expectations in Zambia align with international trends that emphasize the importance of visualization in mathematics learning. However, the extent to which these expectations are realized in classrooms depends on teachers' capacity to implement graphical methods effectively—a central concern of this study.

2.6 Traditional Approaches to Teaching Coordinate Geometry

Research from multiple contexts suggests that traditional approaches to teaching coordinate geometry often emphasize algebraic procedures over graphical understanding. The Russian researcher (2024) notes that "teachers rarely use the coordinate method in solving plan

metric problems", despite the coordinate method being inherently suited to such problems. This observation suggests disconnect between the nature of the content and the methods teachers employ.

Chisenga and Zulu (2021) compared the use of GeoGebra software with "traditional teaching methods (demonstration, discussion, question and answer and expository methods)" in teaching geometric transformations. Their characterization of traditional methods as teacher-centered and expository aligns with broader critiques of mathematics instruction that prioritizes procedural fluency over conceptual understanding. In the Zambian context, traditional teaching methods remain prevalent, particularly in schools with limited resources. The classroom observations that would form part of the present study at Chainta, Chalimbana, and Chongwe Secondary Schools would likely reveal a mix of approaches, with some teachers relying primarily on chalkboard demonstrations while others incorporate more interactive graphical activities.

2.7 Use of Physical Manipulative and Models

Physical manipulative have a long history in mathematics education, and several studies have examined their effectiveness in teaching geometry. Saidu and Bunyamin (2016) investigated the effects of using geoboards and geographical globes on students' performance in mathematics in Kaduna State, Nigeria. Their study, which involved 350 students randomly selected from four secondary schools, used a quasi-experimental design with pretest and posttest measures. The findings supported the effectiveness of these manipulatives in enhancing student performance.

The geoboard is particularly relevant to coordinate geometry instruction. It consists of a grid of pegs on which learners can stretch rubber bands to form geometric shapes. By overlaying a coordinate system on the geoboard, teachers can help learners visualize how coordinates correspond to positions and how geometric properties emerge from coordinate relationships. Saidu and Bunyamin's (2016) research provides evidence from the African context that such manipulatives can improve learning outcomes.

However, the availability of manipulatives in Zambian schools varies considerably. While well-resourced schools may have access to commercial manipulatives, many schools rely on teacher-made materials or do without. The infrastructure improvements in Chongwe District, including new classroom

blocks at Chalimbana and Chongwe Secondary Schools (Chongwe Municipal Council, 2025), create better physical environments for learning but do not automatically provide the instructional materials needed for graphical method instruction.

2.8 Integration of Technology: GeoGebra and Other Digital Tools

The integration of technology into mathematics instruction has expanded dramatically in recent decades, and coordinate geometry has been a particular focus of technology-enhanced teaching. GeoGebra, dynamic mathematics software that combines geometry, algebra, and calculus, has been widely adopted in mathematics classrooms worldwide.

Chisenga and Zulu (2021) conducted a rigorous study of GeoGebra use in teaching geometric transformations at a Zambian STEM secondary school. Using a quasi-experimental design with two intact Grade 12 classes (experimental group $n=38$, control group $n=37$), they found a significant difference in academic achievement between the group taught with GeoGebra and the group taught with traditional methods [$t(df=73)=2.576$, $p=0.012$, $\alpha=0.05$ two-tailed]. The GeoGebra software had positive effects on learners' academic achievement. Additionally, the motivation results indicated that "learners' motivation to learn Geometrical Transformations was enhanced more in the experimental group compared to the control group with motivation mean of 4.33 (SD=0.785) and 3.66 (SD=1.147) respectively".

This Zambian study provides strong evidence for the effectiveness of technology-enhanced graphical methods in teaching coordinate geometry. Importantly, the study also found that "GeoGebra software allowed male and female learners to learn Geometrical Transformations at the same level and this led to a conclusion that GeoGebra software is not discriminatory and impacts positively on gender". This finding has significant implications for equity in mathematics education.

The Russian researcher (2024) also advocates for the use of GeoGebra in teaching the coordinate method, proposing a methodology that features "visual modeling of the drawing construct based on the use of GeoGebra". The emphasis on visual modeling aligns with the graphical focus of the present study.

However, the integration of technology in Zambian schools faces significant barriers. Chisenga and Zulu (2021) recommend that "teachers of mathematics should be encouraged to use GeoGebra in their teaching of Geometrical Transformations" and that "the use of GeoGebra should be emphasised and teachers of mathematics to be trained by those with knowledge on how to use the software during continuing professional development meetings in schools". These recommendations acknowledge that technology integration requires not only hardware and software but also teacher training and ongoing support.

2.9 Classroom Practices: The Slow Reveal Approach

The slow reveal graph routine described by Joswick et al. (2026) offers an innovative approach to teaching the coordinate plane that differs from traditional methods. Rather than presenting the complete coordinate system at once, the teacher gradually unveils components, inviting students to notice, wonder, hypothesize, and revise their thinking. This routine promotes sense-making and positions students as active participants in constructing mathematical understanding.

The adaptation of this routine to the coordinate plane, described as "That's Where I Sit!", involved transforming the classroom seating arrangement into a coordinate grid. Students experienced coordinates in a physical, embodied way before moving to abstract representations. The authors provide examples of classroom dialogue that illustrate how the routine supported mathematical discourse and normalized conjecture and error.

While this research comes from the United States, its principles are transferable to Zambian contexts. The emphasis on student discourse, gradual revelation of mathematical structure, and connections to lived experience aligns with learner-centred pedagogies that are increasingly emphasised in Zambian educational policy. Teachers at Chainda, Chalimbana, and Chongwe Secondary Schools might adapt such routines to their own classroom contexts, using local resources and addressing local needs.

2.10 Teacher Knowledge and Preparedness

The effectiveness of graphical methods depends critically on teachers' knowledge and preparedness. This includes both content knowledge (understanding coordinate geometry deeply) and pedagogical content knowledge (understanding how to teach it effectively).

Mashingaidze (2012) emphasises that teachers must understand students' prior knowledge before designing instruction. This understanding is particularly important in coordinate geometry, which draws on multiple prerequisite skills including vectors, construction, symmetry, properties of shapes, Cartesian equations and graphs, similarity, and congruency. When teachers lack awareness of these prerequisites, they may inadvertently assume knowledge that students do not possess, leading to learning difficulties.

The Russian researcher (2024) notes that teachers rarely use the coordinate method in solving plan metric problems, suggesting gaps in their own comfort with and understanding of graphical approaches. This observation aligns with broader findings that teachers tend to teach as they were taught; perpetuating traditional methods even when alternative approaches might be more effective.

In the Zambian context, teacher preparation programs vary in their emphasis on graphical methods and technology integration. While colleges of education and universities include mathematics methodology courses, the practical implementation of graphical methods depends on factors such as access to resources, class size, and assessment pressures. The surge in enrolment in Chongwe District schools (The Agency Media, 2025) has increased class sizes, potentially making it more difficult for teachers to implement interactive graphical activities that require individual attention and hands-on engagement.

2.11 Graphical Methods in Mathematics Teaching

Graphical methods refer to instructional strategies that use visual representations such as graphs, diagrams, charts, and coordinate planes to explain mathematical concepts. Graphical representation is particularly important in mathematics because many mathematical relationships can be better understood visually. Studies in mathematics education show that graphical representations improve learners' understanding of abstract mathematical ideas. Graphs allow learners to observe patterns, trends, and relationships between variables.

Research on graphing in STEM education indicates that constructing and interpreting graphs plays an important role in developing mathematical understanding. Studies have shown that graphing activities improve students' ability to interpret data and understand relationships between variables.

Graphical methods are widely used in teaching topics such as linear equations, quadratic functions, and coordinate geometry. Teachers often use graphs to demonstrate how algebraic equations correspond to geometric shapes.

In addition to traditional graphs drawn on paper or chalkboards, modern teaching methods increasingly incorporate digital tools such as graphing software and dynamic geometry applications. These technologies enable learners to interact with graphs and observe how changes in variables affect graphical representations.

2.12 Importance of Visualization in Mathematics Learning

Visualization plays a crucial role in the learning of mathematics. Mathematical ideas are often abstract and difficult for learners to understand without visual representation. Visualization helps learners form mental images of mathematical relationships and structures. Educational psychologists have long emphasized the role of visualization in learning. Visual representations such as diagrams and graphs allow learners to organize information and interpret mathematical relationships more effectively.

In geometry education, visualization helps learners develop spatial reasoning and conceptual understanding. Studies show that the use of diagrams, models, and graphical representations enhances learners' comprehension of geometric concepts. Recent research on geometry education highlights the increasing importance of visual tools in mathematics teaching. Studies show that dynamic geometry software and graphical tools support deeper conceptual understanding and improve learners' engagement with geometric concepts. Visualization is therefore considered an important instructional strategy in mathematics education because it enables learners to connect symbolic expressions with graphical representations.

2.13 Teachers' Instructional Strategies in Teaching Coordinate Geometry

Teachers play a central role in determining how mathematical concepts are presented in the classroom. Effective teaching strategies are essential for helping learners understand coordinate geometry concepts.

Instructional strategies commonly used in teaching coordinate geometry include: Graph drawing and interpretation, Demonstration using coordinate planes, Problem-solving

activities involving graphs, Use of mathematical software and graphing tools and Group discussions and collaborative learning. Studies show that learner-centered teaching approaches are more effective than traditional lecture methods in mathematics education. When teachers involve learners in constructing graphs and analyzing graphical relationships, learners develop deeper conceptual understanding.

Modern instructional approaches also encourage the integration of technology in mathematics teaching. Research shows that tools such as GeoGebra and graphing calculators enhance students' understanding of coordinate geometry by allowing them to visualize mathematical relationships dynamically. These tools enable learners to manipulate graphs and observe how changes in equations affect graphical representations.

2.14 Role of Technology in Graphical Teaching Methods

The integration of technology has significantly transformed mathematics teaching. Digital tools provide interactive platforms for visualizing mathematical concepts. Dynamic geometry software such as GeoGebra allows learners to construct and manipulate graphs in real time. These tools help learners explore mathematical relationships and test mathematical hypotheses.

Research studies show that the use of GeoGebra improves students' understanding of coordinate geometry concepts. For example, a study conducted in Nigerian secondary schools found that students taught using GeoGebra-assisted instruction performed better in coordinate geometry than those taught using traditional lecture methods. Similarly, other studies have shown that visualization tools enhance students' comprehension of geometric concepts and increase engagement in mathematics lessons. Despite these benefits, effective use of technology in teaching requires adequate teacher training and access to appropriate resources.

2.15 Theoretical Perspectives on Learning Geometry

Several theories have been developed to explain how learners understand geometry and graphical representations. One of the most widely recognized theories in geometry education is the Van Hiele Model of Geometric Thinking. The model was developed by Dutch educators Dina van Hiele-Geldof and Pierre van Hiele. The theory describes different levels through which learner's progress as they develop geometric understanding.

The levels include: Visualization level, Analysis level, Informal deduction level, Deduction level and Rigor level.

According to this model, learners must progress through these levels sequentially in order to develop advanced geometric reasoning skills. Teachers therefore need to use instructional strategies that match learners' cognitive levels. Graphical methods play an important role in helping learners move from the visualization stage to higher levels of geometric understanding.

2.16 Empirical Studies on Graphical Methods in Mathematics

Several empirical studies have examined the impact of graphical teaching methods on students' learning outcomes. Research findings generally indicate that graphical approaches improve learners' conceptual understanding of mathematical concepts. Graphical methods help learners interpret mathematical relationships and solve problems more effectively.

Studies in mathematics education have also shown that graphical representation enhances students' ability to interpret functions and equations. When learners actively participate in graph construction activities, they develop stronger problem-solving skills. Additionally, research shows that technology-based graphical tools significantly improve learners' spatial reasoning and conceptual understanding of geometry. These findings highlight the importance of incorporating graphical methods into mathematics teaching.

2.17 Challenges in Using Graphical Methods in Mathematics Teaching

Although graphical methods are widely recommended in mathematics teaching, teachers may face several challenges when implementing these methods.

Common challenges include:

Lack of Teaching Resources; Many schools lack adequate teaching materials such as graph boards, projectors, and computers needed for graphical instruction.

Limited Teacher Training; some teachers may not have sufficient training in using graphical teaching strategies or digital tools.

Large Class Sizes; Large class sizes can make it difficult for teachers to engage learners in practical graph construction activities.

Time Constraints; the pressure to complete the syllabus may limit teachers' ability to conduct interactive graphical activities in the classroom.

Studies suggest that addressing these challenges requires improved teacher training, provision of instructional resources, and supportive educational policies.

2.18 Research Gap

Although many studies have examined the use of graphical methods in mathematics teaching, there is limited research focusing specifically on how teachers in Zambian secondary schools use graphical methods when teaching coordinate geometry. Most existing studies focus on technology integration or general geometry teaching practices rather than teachers' specific instructional approaches in coordinate geometry. Therefore, this study seeks to fill this gap by investigating teachers' use of graphical methods in teaching coordinate geometry in Zambian secondary schools.

Graphical method instruction requires materials: graph paper, rulers, geoboards, compasses, protractors, and ideally computers or tablets with dynamic geometry software. In many Zambian schools, these materials are in short supply. The infrastructure improvements in Chongwe District (Chongwe Municipal Council, 2025) have addressed classroom space but not necessarily instructional materials.

The surge in enrolment in Chongwe District schools (The Agency Media, 2025) has increased demand for materials without necessarily increasing supply. When 90,000 learners must share limited resources, individual hands-on experience with graphical materials becomes difficult to provide.

Technology Infrastructure Gaps: Even when schools have computers, they may lack reliable electricity, internet connectivity, or technical support. Chisenga and Zulu's (2021)

study at a STEM secondary school likely benefited from better technology infrastructure than is available at many ordinary secondary schools. At Chainda, Chalimbana, and Chongwe Secondary Schools, technology access may be limited, constraining teachers' ability to use software like GeoGebra. The digital divide between well-resourced and under-resourced schools is a persistent challenge in Zambian education. While initiatives such as CDF investments aim to address infrastructure gaps, the pace of change is slow relative to need.

Large Class Sizes: The 70% increase in enrolment in Chongwe District (The Agency Media, 2025) has inevitably led to larger class sizes. Large classes make it difficult for teachers to implement interactive graphical activities, provide individual feedback, or ensure that all learners can see demonstrations clearly. When classes are overcrowded, teachers may default to lecture-based instruction that minimizes these logistical challenges but also minimizes opportunities for hands-on graphical learning.

2.19 Summary of the Literature Review

This chapter reviewed literature related to graphical methods in mathematics teaching, visualization in mathematics learning, instructional strategies used by teachers, and empirical studies on graphical teaching methods. The literature shows that graphical methods play an important role in helping learners understand coordinate geometry concepts. Visualization tools and graphical representations enhance conceptual understanding and improve learners' engagement with mathematical ideas. However, several challenges may affect teachers' ability to effectively use graphical methods in the classroom.

The review also identified a gap in research focusing on the use of graphical methods in teaching coordinate geometry in Zambian secondary schools. This study therefore aims to contribute to existing knowledge by examining teachers' instructional practices and identifying strategies for improving mathematics teaching

III. RESEARCH METHODOLOGY

This chapter presents the research methodology employed in investigating teachers' use of graphical methods in teaching coordinate geometry in selected secondary schools in Chongwe District, Lusaka Province. The methodology serves as the blueprint that guides the systematic investigation of the research problem, ensuring that the findings are credible, trustworthy, and applicable to educational practice. As noted by Shields, Schartner, and Curtis (2024), research methodology in education requires careful consideration of the philosophical underpinnings, strategic approaches, and practical methods that collectively enable researchers to address their research questions effectively.

The study focuses on three secondary schools in Chongwe District: Chainda Secondary School, Chalimbana Secondary

School, and Chongwe Secondary School. These institutions were selected based on their accessibility, representation of different geographical contexts within the district, and the presence of mathematics teachers actively engaged in teaching coordinate geometry at the secondary school level. Recent developments in these schools, including infrastructure improvements through Constituency Development Fund (CDF) projects, have enhanced the learning environment and potentially influenced teaching practices (Chongwe Municipal Council, 2025; Lusaka Provincial Administration, 2024).

This chapter is structured to provide a comprehensive account of the research process. It begins by establishing the research design and its philosophical foundations, followed by a detailed description of the target population, sample size determination, and sampling techniques employed. The chapter subsequently describes the research instruments developed for data collection, the procedures followed in gathering data, the analytical approaches used to make sense of the collected information, and the ethical considerations that guided the entire research process. Each section is supported by relevant methodological literature and includes justifications for the choices made in the context of studying graphical methods in coordinate geometry instruction.

3.2 Research Design

The research design constitutes the overall strategy that integrates the different components of the study in a coherent and logical manner, ensuring that the research problem is effectively addressed. According to Coe et al. (2025), research design in education involves making principled decisions about how evidence will be gathered and interpreted to provide convincing answers to research questions. The design chosen for this study reflects both the nature of the research problem and the practical considerations of conducting research in school settings.

3.2.1 Philosophical Underpinnings

This study is grounded in a pragmatic philosophical worldview, which prioritizes the research question above all other considerations and allows for the integration of multiple approaches to data collection and analysis. Pragmatism recognizes that research methods should be chosen based on their appropriateness for addressing the research questions rather than on rigid adherence to particular philosophical traditions (Shields et al., 2024). In the context of investigating teachers' use of graphical methods in teaching coordinate

geometry, pragmatism enables the researcher to capture both the measurable aspects of teaching practice and the nuanced experiences and perspectives of teachers and students.

The pragmatic approach acknowledges that teaching mathematics involves both observable behaviors and complex cognitive and social processes that cannot be reduced to simple measurements. As Mashingaidze (2012) observed in his study of geometric transformations at the secondary school level, understanding how teachers approach graphical methods requires attention to both the visible instructional strategies and the underlying pedagogical reasoning that guides teachers' decisions. This philosophical stance allows for the collection of quantitative data about the frequency and types of graphical methods used, alongside qualitative data about teachers' experiences, challenges, and perceptions.

3.2.2 Mixed-Methods Case Study Design

This study employs a mixed-methods case study design, combining quantitative and qualitative approaches within a multiple-case study framework. The case study approach is particularly appropriate for investigating contemporary phenomena within real-life contexts, especially when the boundaries between the phenomenon and context are not clearly evident (Coe et al., 2025). In this research, the phenomenon of interest teachers' use of graphical methods in teaching coordinate geometry is inherently embedded in the specific contexts of the three selected secondary schools. The multiple-case design involves treating each school as a distinct case, allowing for within-case analysis and cross-case comparison. This approach enables the researcher to identify patterns and themes that are consistent across different school contexts, as well as unique features that may be specific to particular settings. As Shields et al. (2024) note, multiple-case designs enhance the external validity or transferability of findings by demonstrating that observed phenomena are not unique to a single setting.

First, it enables triangulation, whereby findings from different sources can be compared and corroborated. For example, data from classroom observations about the use of graphing calculators can be compared with teachers' self-reports in questionnaires and their explanations during interviews. Second, it allows for complementarity, where qualitative data provide depth and meaning to quantitative findings. Understanding not only how often teachers use particular graphical methods but also why they choose or avoid certain

approaches requires qualitative exploration. Third, the design supports development, where findings from one method inform the application of another method. Preliminary questionnaire data can guide the selection of interview participants and the focus of classroom observations (Shields et al., 2024).

3.2.3 Justification for the Case Study Approach

The choice of a case study design is justified by several considerations specific to this research. The teaching of coordinate geometry through graphical methods is a complex instructional practice that cannot be adequately understood through decontextualized surveys or experiments alone. As demonstrated in the work of Joswick, Williams, and Felton-Koestler (2026), innovative approaches to teaching the coordinate plane, such as the "Slow Reveal" routine, derive their meaning and effectiveness from their implementation in specific classroom contexts. Capturing such contextualized practice requires research approaches that are sensitive to the unique circumstances of each teaching and learning environment.

Furthermore, the three selected schools Chainda, Chalimbana, and Chongwe Secondary Schools represent different contexts within Chongwe District. Chalimbana Secondary School, for instance, has recently benefited from infrastructure development that has expanded classroom space and potentially influenced teaching conditions (Lusaka Provincial Administration, 2024). Chongwe Secondary School, as a more established institution, may have different resources and teaching traditions. A case study design allows for the examination of how these contextual factors interact with teachers' use of graphical methods.

3.3 Target Population

The target population for this study comprises all mathematics teachers and students in secondary schools within Chongwe District, Lusaka Province, who are involved in teaching and learning coordinate geometry. According to Shields et al. (2024), defining the target population is a critical step in research design, as it establishes the boundaries within which the study's findings can be generalized and ensures that the sample selected is representative of the population of interest.

3.3.1 Characteristics of the Target Population

Chongwe District is one of several districts in Lusaka Province and includes a mix of urban, peri-urban, and rural settlements. The district has experienced significant educational

development in recent years, with investments in school infrastructure through the Constituency Development Fund (Chongwe Municipal Council, 2025). This development has included the construction of new classroom blocks at schools such as Chalimbana Secondary School and improvements at Chainda and Chongwe Secondary Schools.

The target population includes mathematics teachers who are qualified to teach at the secondary school level and who have experience teaching coordinate geometry as part of the Zambian mathematics curriculum. Coordinate geometry is a fundamental topic in secondary school mathematics, appearing in various grade levels and forming the basis for more advanced mathematical concepts (Mashingaidze, 2012). Teachers in the target population are expected to have knowledge of the Zambian mathematics syllabus and experience in implementing instructional strategies for teaching coordinate geometry.

Students in the target population are those enrolled in secondary school grades where coordinate geometry is taught. These students have varying levels of mathematical background and exposure to graphical methods. Their perspectives are valuable for understanding how graphical methods influence learning and engagement with coordinate geometry concepts.

3.3.2 Definition of the Accessible Population

From the broader target population, an accessible population was defined for practical purposes. The accessible population consists of mathematics teachers and students in three selected secondary schools within Chongwe District: Chainda Secondary School, Chalimbana Secondary School, and Chongwe Secondary School. These schools were selected based on the following criteria:

1. **Geographic accessibility:** All three schools are accessible by road and within reasonable distance from the district center, facilitating data collection visits.
2. **Diversity of contexts:** The schools represent different contexts within the district, with Chalimbana located in a more rural setting, Chainda in a peri-urban area, and Chongwe in the district town.
3. **Presence of secondary school mathematics programs:** All three schools offer full secondary education programs that include coordinate geometry in their mathematics curricula.

4. **Willingness to participate:** Preliminary consultations with school administrators indicated willingness to participate in educational research.

The accessible population includes all mathematics teachers currently teaching at these schools who have responsibility for teaching coordinate geometry content. It also includes students in grades where coordinate geometry is taught, particularly those who have recently completed or are currently engaged in coordinate geometry instruction.

3.3.3 Size and Composition of the Accessible Population

Based on information gathered from school records and preliminary visits, the accessible population comprises:

Chainda Secondary School: Approximately 8 mathematics teachers, including those specializing in upper secondary and those teaching lower secondary grades. The school serves a peri-urban community and has experienced growth in enrollment following infrastructure improvements.

Chalimbana Secondary School: Approximately 10 mathematics teachers. As noted by the school headmaster, Chalimbana Secondary School is the only school in the ward offering secondary education to male children, making it a significant educational institution in the area (Lusaka Provincial Administration, 2024). The school has recently benefited from new classroom construction, potentially affecting teaching conditions. **Chongwe Secondary School:** Approximately 12 mathematics teachers. As the district's main secondary school, it has a larger teaching staff and more established mathematics department.

The total accessible population of mathematics teachers across the three schools is approximately 30 individuals. In addition, the student population in grades where coordinate geometry is taught (typically Grades 10-12) numbers several hundred across the three schools. This accessible population provides an adequate base for sampling and data collection.

3.4 Sample Size

Determining an appropriate sample size is crucial for ensuring that research findings are representative and that statistical analyses have sufficient power to detect meaningful patterns. According to Coe et al. (2025), sample size decisions in educational research involve balancing statistical requirements with practical constraints such as time, resources, and access to participants.

3.4.1 Teacher Sample Size

For the teacher component of this study, a sample of 30 mathematics teachers was targeted, representing the entire accessible population of mathematics teachers across the three

schools. This approach, known as a census sample for the teacher population, was feasible given the manageable size of the total teacher population (approximately 30 teachers). Including all mathematics teachers in the sample offers several advantages:

First, it eliminates sampling error for the teacher population, ensuring that the findings accurately represent the views and practices of all mathematics teachers in the three schools. Second, it maximizes the statistical power for analyses comparing subgroups of teachers (e.g., by school, years of experience, or qualifications). Third, it ensures that teachers with potentially unique perspectives or practices are not excluded from the study. The decision to include all mathematics teachers is supported by Shields et al. (2024), who note that when the total population is small and accessible, a census approach is preferable to sampling because it provides complete information and avoids the uncertainties associated with sample estimates.

3.4.2 Student Sample Size

For the student component, a sample of 150 students was targeted, with approximately 50 students from each of the three schools. This sample size was determined based on several considerations:

1. **Representation across grade levels:** Students were selected from Grades 10, 11, and 12 to ensure representation across the secondary school grades where coordinate geometry is taught.
2. **Statistical adequacy:** A sample of 150 students provides adequate statistical power for descriptive analyses and for detecting moderate differences between schools or grade levels.
3. **Practical feasibility:** Collecting data from 150 students is manageable within the time and resource constraints of the study, while still providing sufficient breadth of perspectives.

The student sample was drawn from classes where coordinate geometry had recently been taught or was currently being taught, ensuring that students had relevant experiences to reflect upon when responding to questionnaires and participating in focus group discussions.

3.4.3 Classroom Observation Sample

For classroom observations, a sample of 15 lessons was targeted, representing approximately five lessons per school. This sample size was determined based on the need to observe a range of teaching practices while acknowledging the practical constraints of scheduling observations across multiple schools and teachers.

The observation sample included:

1. Lessons taught by different teachers within each school, representing varying levels of experience and teaching styles.
2. Lessons covering different aspects of coordinate geometry, such as plotting points, graphing linear equations, transformations, and applications.
3. Lessons at different grade levels, from introductory to advanced coordinate geometry topics.

This approach to sampling observations aligns with recommendations by Coe et al. (2025) that observational studies in education should sample across teachers, topics, and contexts to capture the range of practice rather than focusing on a small number of potentially atypical lessons.

3.4.4 Interview Sample Size

For in-depth interviews, a sample of 12 teachers was targeted, with four teachers selected from each school. This sample size was determined based on the principles of qualitative sampling, which prioritize depth of information over breadth of representation. According to Shields et al. (2024), qualitative samples in educational research are typically smaller than quantitative samples because the goal is to achieve rich, detailed understanding of phenomena rather than statistical generalization.

The interview sample was selected purposefully to include teachers with diverse characteristics:

1. Teachers with varying years of teaching experience (early career, mid-career, and experienced)
2. Teachers with different qualifications (diploma, bachelor's degree, postgraduate qualifications)
3. Teachers known for using diverse teaching methods, including those who frequently use graphical approaches and those who rely more on algebraic or theoretical approaches. This diversity ensures that the interview data capture a range of perspectives and experiences related to using graphical methods in teaching coordinate geometry.

3.4.5 Focus Group Sample

For focus group discussions, a sample of 30 students was targeted, with three focus groups of approximately 10 students each—one focus group per school. Focus groups provide an efficient means of gathering qualitative data from multiple participants simultaneously and capitalize on group interaction to generate rich discussions (Coe et al., 2025).

The focus group sample was drawn from the larger student sample and included students from different grade levels and with varying levels of performance in mathematics. This diversity ensures that the focus group discussions capture a range of student experiences and perspectives on graphical methods in coordinate geometry instruction.

Table 1: Summary of Sample Size

Participant category	Chainda SS	Chalimbana SS	Chongwe SS	Total
Mathematics teachers(census)	8	10	12	30
Student(Questionnaire)	50	50	50	150
Classroom Observations	5	5	5	15
Teacher Interviews	4	4	4	12
Focus Groups	1(10 students)	1(10 students)	1(10 students)	3(30 students)

3.5 Sampling Technique

The sampling techniques employed in this study reflect the mixed-methods design and the need to address different aspects of the research questions through appropriate selection strategies. According to Shields et al. (2024), sampling in educational research should be guided by the research questions, the nature of the population, and the intended use of findings. This study employs a combination of probability and non-probability sampling techniques, each serving specific purposes within the overall research design.

3.5.1 Purposive Sampling of Schools

The three schools in this study Chainda Secondary School, Chalimbana Secondary School, and Chongwe Secondary School were selected through purposive sampling. Purposive sampling involves deliberately selecting cases that are likely to provide rich and relevant information related to the research questions (Coe et al., 2025).

The selection criteria for schools included:

1. **Geographic diversity:** Representing different settlement types within Chongwe District (peri-urban, rural, and urban)
2. **Institutional history:** Including both established schools and those that have recently benefited from infrastructure development
3. **Accessibility:** Ensuring that schools were accessible for multiple research visits
4. **Willingness to participate:** Selecting schools where administrators expressed interest in the research and commitment to facilitating data collection.

This purposive approach ensures that the cases selected are information-rich and capable of illuminating the phenomenon under investigation. As noted by Shields et al. (2024), purposive sampling is particularly appropriate in case study research where the goal is to select cases that will yield deep understanding rather than statistical representativeness.

3.5.2 Census Sampling for Teachers

For mathematics teachers within the selected schools, a census sampling approach was employed. Census sampling involves including all members of a defined population in the study (Shields et al., 2024). This approach was feasible because the total number of mathematics teachers across the three schools (approximately 30) was manageable for data collection.

The census approach eliminates sampling error and ensures that the teacher data fully represent the population of mathematics teachers in the three schools. It also maximizes the statistical power for within-school and between-school analyses. All mathematics teachers who were currently teaching at the schools and who had responsibility for teaching coordinate geometry content were invited to participate in the study.

3.5.3 Stratified Random Sampling for Students

For the student questionnaire, a stratified random sampling technique was employed. Stratified random sampling involves dividing the population into relevant subgroups (strata) and then drawing random samples from each subgroup (Coe et al., 2025). This approach ensures that important subgroups are adequately represented in the sample.

The stratification variables for student sampling were:

1. School: Chainda, Chalimbana, and Chongwe Secondary Schools

2. **Grade level: Grades 10, 11, and 12** Within each school and grade level, students were randomly selected from class lists. This approach ensures that the student sample represents the distribution of students across schools and grade levels while maintaining the benefits of random selection. The sample size of 50 students per school (approximately 16-17 students per grade level) provides adequate representation of each stratum.

The use of stratified random sampling is justified by the need to capture potential differences in student experiences and perceptions across schools and grade levels. Students in different grades have varying levels of exposure to coordinate geometry, with Grade 12 students having studied the topic more extensively than Grade 10 students. Ensuring representation across grades allows for analysis of these developmental differences.

3.5.4 Purposive Sampling for Interviews

For teacher interviews, a purposive sampling technique was employed to select information-rich cases from among the mathematics teachers who completed questionnaires. Purposive sampling in qualitative research involves intentionally selecting participants who have particular characteristics or experiences relevant to the research questions (Shields et al., 2024).

The purposive selection criteria for interview participants included:

1. Years of teaching experience: Including early-career teachers (0-5 years), mid-career teachers (6-15 years), and experienced teachers (16+ years)
2. Educational qualifications: Including teachers with diplomas, bachelor's degrees, and postgraduate qualifications
3. Reported use of graphical methods: Including teachers who reported frequent use of graphical methods, those who reported moderate use, and those who reported limited use
4. Teaching assignments: Including teachers responsible for different grade levels and mathematics topics
5. Willingness to participate: Selecting teachers who expressed interest in discussing their teaching practices in depth.
6. This purposive approach ensures that the interview data capture diverse perspectives and experiences related to using graphical methods in teaching coordinate geometry. By including teachers with varying characteristics, the

study can explore how different factors influence teachers' approaches to graphical instruction.

3.5.5 Convenience Sampling for Classroom Observations

For classroom observations, a convenience sampling approach was employed, with observations scheduled based on teachers' availability and the timing of coordinate geometry instruction. Convenience sampling involves selecting cases that are readily available and accessible to the researcher (Coe et al., 2025).

While convenience sampling has limitations in terms of representativeness, it is often necessary in school-based research where researchers must work within teachers' schedules and the natural flow of the curriculum. To mitigate potential biases associated with convenience sampling, efforts were made to:

- Schedule observations across different days of the week and times of day
 - Observe lessons covering different topics within coordinate geometry
 - Include observations of teachers with varying characteristics and teaching styles
- Conduct observations over an extended period to capture normal variation in teaching practice

3.5.6 Purposive Sampling for Focus Groups

For student focus groups, a purposive sampling technique was employed to select participants from among the students who completed questionnaires. The purposive criteria for focus group selection included:

- **Grade level representation:** Including students from Grades 10, 11, and 12 in each focus group
- **Gender balance:** Ensuring approximately equal numbers of male and female students
- **Performance diversity:** Including students with varying levels of mathematics achievement
- **Willingness to participate:** Selecting students who expressed interest in discussing their learning experiences

The focus groups were designed to be small enough (approximately 10 students) to allow all participants to contribute while large enough to generate diverse perspectives and group interaction.

3.6 Research Instruments

The data collection instruments for this study were developed to address the different research questions and to capture both quantitative and qualitative data. According to Shields et al. (2024), research instruments in educational studies should be carefully designed, piloted, and validated to ensure that they yield trustworthy data that accurately represent the phenomena under investigation. This section describes the four main instruments employed in this study: the Mathematics Teacher Questionnaire, the Classroom Observation Protocol, the Semi-Structured Interview Guide, and the Student Focus Group Guide.

3.6.1 Mathematics Teacher Questionnaire

The Mathematics Teacher Questionnaire was developed to collect quantitative data on teachers' background characteristics, their use of graphical methods in teaching coordinate geometry, and their perceptions of factors influencing their instructional choices. The questionnaire was designed to be comprehensive yet manageable, requiring approximately 30-40 minutes for completion.

Structure and Content

The questionnaire was organized into four sections:

Section A: Demographic and Professional Background Information

This section collected data on teachers' age, gender, highest educational qualification, years of teaching experience, mathematics teaching load, and professional development experiences related to mathematics instruction. This information enables analysis of how teacher characteristics relate to their use of graphical methods.

Section B: Use of Graphical Methods in Coordinate Geometry Instruction

This section presented a list of graphical methods potentially used in teaching coordinate geometry, including:

- Plotting points on the Cartesian plane
- Drawing graphs of linear equations
- Using graphing calculators or computer software
- Employing graph boards and chalkboard grids
- Using real-life examples and manipulative
- Implementing transformation geometry activities (translations, reflections, rotations)
- Using coordinate geometry to solve practical problems
- Incorporating visual aids and diagrams in explanations

For each method, teachers were asked to indicate the frequency of use on a five-point Likert scale (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always). Additional items explored the specific topics within coordinate geometry where different methods are employed and the grade levels where graphical approaches are emphasized.

Section C: Factors Influencing the Use of Graphical Methods

This section presented a series of statements about potential influences on teachers' use of graphical methods, including:

- Curriculum requirements and syllabus guidance
Availability of resources and teaching materials
- Class size and classroom conditions
- Student background and prior knowledge
- Teacher training and professional development
Time constraints and lesson pacing
- Assessment demands and examination preparation
- Personal beliefs about mathematics teaching and learning

Teachers rated the extent to which each factor influenced their use of graphical methods on a five-point Likert scale (1 = Not at all influential, 2 = Slightly influential, 3 = Moderately influential, 4 = Very influential, 5 = Extremely influential).

Section D: Open-Ended Questions

This section included open-ended questions inviting teachers to elaborate on their experiences with graphical methods, describe successful lessons, identify challenges they face, and suggest improvements that could enhance their use of graphical approaches in teaching coordinate geometry.

Questionnaire Development and Validation

The questionnaire was developed through a multi-stage process. First, an initial draft was created based on a review of literature on teaching coordinate geometry and graphical methods in mathematics education. This literature included studies on innovative approaches such as the "Slow Reveal" routine described by Joswick et al. (2026) and the graphical approach to transformations advocated by Mashingaidze (2012).

Second, the draft questionnaire was reviewed by a panel of experts, including two mathematics education specialists and one research methodology expert. These experts assessed the questionnaire for content validity, clarity, and appropriateness

for the Zambian secondary school context. Their feedback was used to revise and refine the instrument.

Third, the questionnaire was piloted with five mathematics teachers from a school not included in the main study. The pilot served several purposes:

- Identifying ambiguous or unclear
- items Assessing the time required for completion
- Testing the appropriateness of response scales
- Gathering feedback on the overall structure and flow

Based on the pilot results, further revisions were made to improve clarity and relevance. The final questionnaire demonstrated good internal consistency, with Cronbach's alpha coefficients exceeding 0.70 for the main scales.

3.6.2 Classroom Observation Protocol

The Classroom Observation Protocol was developed to systematically document teachers' use of graphical methods during actual classroom instruction. Observation provides direct evidence of teaching practices that complements teachers' self-reports in questionnaires and interviews.

Structure and Content

The observation protocol was designed to capture both quantitative and qualitative data during lesson observations. It included the following components:

Pre-Observation Information

- School, teacher, grade level, and topic
- Number of students present
- Classroom layout and available resources
- Lesson objectives as stated by the teacher

Observation Checklist

The checklist included items related to:

- Types of graphical methods employed (plotting points, drawing graphs, using technology, etc.)
- Frequency and duration of graphical activities
Teacher demonstrations and explanations
- Student engagement with graphical representations
- Use of teaching aids (graph boards, charts, calculators, etc.)
- Integration of graphical methods with algebraic and theoretical approaches

- Observers recorded the presence or absence of each method and made notes on how methods were implemented.

Time Sampling

The protocol included a time sampling component, with observers recording at five-minute intervals the primary instructional activity and the role of graphical methods in that activity. This approach enables analysis of the proportion of lesson time devoted to different types of graphical work.

Narrative Notes

The protocol provided space for detailed narrative notes describing key episodes in the lesson, including:

- How teachers introduced graphical concepts
- Student questions and responses related to graphical work
- Challenges that arose during graphical activities Creative or innovative uses of graphical methods
- Interactions between teachers and students during graphical tasks

Post-Observation Reflection

Immediately following each observation, the researcher completed a reflection section capturing overall impressions, notable features of the lesson, and questions or issues to explore in follow-up interviews.

Observer Training and Reliability

To ensure consistency across observations, the researcher underwent training in the use of the observation protocol. This training included:

- Studying the protocol and its components in detail Practicing with video-recorded mathematics lessons
- Conducting pilot observations in a school not included in the main study Debriefing with experienced observers to calibrate judgments
- During the main study, periodic reliability checks were conducted by having a second observer (a trained research assistant) accompany the researcher for a subset of observations. Inter-observer agreement exceeded 85% for the main observation categories.

3.6.3 Semi-Structured Interview Guide

The Semi-Structured Interview Guide was developed to explore in depth teachers' experiences, perspectives, and decision-making related to using graphical methods in teaching

coordinate geometry. Semi-structured interviews allow for flexibility in probing emergent themes while ensuring that key topics are covered with all participants (Shields et al., 2024) .

Interview Guide Content

The interview guide included the following main sections:

Opening and Context Setting

- Introduction to the purpose of the interview
- Assurance of confidentiality and informed consent
- Brief review of the teacher's background and teaching context

Teachers' Understanding of Graphical Methods

What do you understand by "graphical methods" in teaching coordinate geometry? How would you describe your overall approach to teaching coordinate geometry? What role do graphical methods play in your teaching of this topic?

Use of Specific Graphical Methods

- Can you describe the graphical methods you use most frequently?
- How do you decide which methods to use for different topics or classes?
- Can you walk me through a recent lesson where you used graphical methods? What did you do, and how did students respond?

Factors Influencing Use of Graphical Methods

- What factors encourage or support your use of graphical methods? What challenges or barriers limit your use of graphical methods?
- How do curriculum requirements, resources, and student factors influence your choices?

Student Engagement and Learning

- How do students typically respond to graphical methods?
- What evidence do you see that graphical methods help students understand coordinate geometry?
- How do you address students who struggle with graphical representations?

Professional Development and Support

- What training have you received related to teaching coordinate geometry or using graphical methods?
- What types of support would help you use graphical methods more effectively?

- Are there resources or professional development experiences you would find valuable? Closing
- Is there anything else you would like to share about your experience with graphical methods?
- Do you have questions for me about the research?

Interview Flexibility and Probing

While the interview guide provided a structure for the conversation, the semi-structured format allowed the researcher to follow interesting lines of discussion, probe for elaboration, and explore unanticipated themes. Probes such as "Can you tell me more about that?" and "What do you mean by...?" were used to deepen responses and clarify meaning.

Interview Duration and Recording

Interviews were scheduled for approximately 45-60 minutes and were conducted at times and locations convenient for teachers (typically in their classrooms or offices after school hours). With participants' permission, interviews were audio-recorded to ensure accurate capture of responses. The researcher also took brief notes during interviews to record key points and observations.

3.6.4 Student Focus Group Guide

The Student Focus Group Guide was developed to gather qualitative data on students' experiences with and perceptions of graphical methods in coordinate geometry instruction. Focus groups capitalize on group interaction to generate rich discussions and reveal diverse perspectives (Coe et al., 2025).

Focus Group Guide Content

The focus group guide included the following components:
Introduction and Ground Rules

- Welcome and introduction of moderator and participants
- Explanation of purpose and confidentiality
- Establishment of ground rules (respect others, one person speaks at a time, no right or wrong answers)
- Ice-Breaker Activity
- Brief introduction of participants (name, grade, favorite mathematics topic)
- Simple warm-up question about experiences in mathematics class Experiences with Coordinate Geometry
- What do you remember learning about coordinate geometry? How did your teacher teach coordinate geometry?

- What kinds of activities did you do when learning about coordinates and graphs? Perceptions of Graphical Methods
- When your teacher uses graphs or drawings to explain coordinate geometry, how does that help you understand?
- Do you prefer when teachers use graphical methods or when they focus on formulas and calculations? Why?
- Can you describe a time when using graphs helped you understand something in mathematics?

Challenges and Difficulties

1. What aspects of coordinate geometry do you find most challenging?
2. When you work with graphs and coordinates, what difficulties do you experience?
3. What could teachers do to help you understand better?

Suggestions for Improvement

- If you could suggest ways to make learning coordinate geometry more interesting or understandable, what would you suggest?
- What kinds of activities or resources would help you learn better?

Closing

- Summary of key points discussed
- Opportunity for participants to add anything
- Thanks and appreciation
-

Focus Group Moderation

Focus groups were moderated by the researcher, with assistance from a trained note-taker. The moderator's role was to facilitate discussion, ensure all participants had opportunities to contribute, and keep the conversation focused on the topic while allowing for natural interaction. The note-taker recorded non-verbal communication, group dynamics, and key points to supplement the audio recordings.

Focus Group Logistics

Each focus group included approximately 10 students and lasted 45-60 minutes. Groups were conducted in quiet, private spaces within the schools (typically empty classrooms or meeting rooms) to minimize distractions and ensure confidentiality. Refreshments were provided to create a comfortable atmosphere.

3.6.5 Instrument Validity and Reliability

Ensuring the validity and reliability of research instruments is essential for producing trustworthy findings. According to

Shields et al. (2024), validity refers to the extent to which an instrument measures what it intends to measure, while reliability refers to the consistency of measurements.

Content Validity

Content validity was established through expert review of all instruments. The panel of experts (two mathematics education specialists and one research methodology expert) assessed whether the instruments adequately covered the domains of interest and whether items were appropriate for the Zambian secondary school context. Their feedback was used to revise and refine the instruments.

Face Validity

Face validity the extent to which instruments appear to measure what they claim to measure—was assessed during the pilot phase. Pilot participants were asked to comment on the clarity, relevance, and appropriateness of items and their feedback informed final revisions. Construct Validity

For the questionnaire, construct validity was assessed through factor analysis of the main scales. The factor structure was examined to ensure that items grouped together in meaningful ways consistent with theoretical expectations. Items that did not load clearly on expected factors were reviewed and, in some cases, revised or removed.

Reliability

Reliability of the questionnaire scales was assessed using Cronbach's alpha, a measure of internal consistency. Alpha coefficients exceeding 0.70 were considered acceptable.

For scales where

Alpha fell below this threshold, items were reviewed and problematic items were revised or removed.

For observation data, inter-observer reliability was assessed through simultaneous observations by two observers for a subset of lessons. Percentage agreement and Cohen's kappa coefficients were calculated to assess consistency.

For qualitative data, reliability was enhanced through:

- Audio-recording and verbatim transcription of interviews and focus groups Detailed documentation of data collection procedures
- Member checking, where participants were given opportunities to review summaries of their responses
- Peer debriefing, where preliminary findings were discussed with colleagues

3.7 Data Collection Procedure

The data collection procedure was carefully planned and executed to ensure systematic gathering of high-quality data while minimizing disruption to school activities. According to Shields et al. (2024), data collection in educational research requires careful attention to logistics, relationships with participating institutions, and adherence to ethical principles. This section describes the step-by-step procedures followed in collecting data for this study.

3.7.1 Gaining Access and Approvals

The data collection process began with obtaining necessary permissions and approvals:

Ethical Clearance

Ethical clearance was obtained from the relevant institutional review board. The application included detailed information about the research purpose, methods, participant recruitment procedures, data protection measures, and plans for ensuring participant welfare. Approval was granted after the board confirmed that the study met ethical standards for research involving human participants.

District Education Office Permission

Permission was sought from the Chongwe District Education Board Secretary (DEBS). A formal letter was submitted describing the research, its purpose, the schools involved, and the proposed data collection activities. The DEBS office reviewed the application and granted written permission to conduct research in schools within the district.

School Administrator Consent

With district permission in hand, the researcher contacted the head teachers of Chainda, Chalimbana, and Chongwe Secondary Schools. Meetings were scheduled with each head teacher to explain the research, discuss the data collection plan, and address any concerns. Head teachers were provided with information sheets and consent forms, and their written consent was obtained before proceeding.

Teacher Recruitment and Consent

Mathematics teachers at each school were invited to participate in an informational meeting where the researcher explained the research purpose, procedures, and ethical protections. Teachers were provided with information sheets and given time to consider participation. Those willing to participate signed consent forms and were included in the study.

IV: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

This chapter presents, analyzes, and interprets the data collected from mathematics teachers and students in Chainda Secondary School, Chalimbana Secondary School, and Chongwe Secondary School regarding teachers' use of graphical methods in teaching coordinate geometry. The chapter is organized according to the research questions that guided this study, with data from multiple sources integrated to provide a comprehensive understanding of the phenomenon under investigation. According to Shields, Schartner, and Curtis (2024), effective data presentation in educational research should enable readers to understand both the patterns and the nuances of findings, with interpretation grounded in relevant literature and theoretical frameworks.

The data presented in this chapter were collected through four main instruments: the Mathematics Teacher Questionnaire (completed by 30 teachers across the three schools), the Classroom Observation Protocol (used to observe 15 lessons), the Semi-Structured Interview Guide (used to conduct in-depth interviews with 12 teachers), and the Student Focus Group Guide (used to facilitate discussions with 30 students across three focus groups). The combination of quantitative and qualitative data allows for triangulation of findings, where evidence from multiple sources can be compared and corroborated to strengthen the validity of conclusions (Coe et al., 2025).

The analysis follows a mixed-methods approach, with quantitative data analyzed using descriptive statistics (frequencies, percentages, means, and standard deviations) and qualitative data analyzed using thematic analysis. The interpretation of findings draws on relevant literature on mathematics education, particularly studies on teaching coordinate geometry and graphical methods in secondary school contexts (Joswick, Williams, & Felton-Koestler, 2026; Mashingaidze, 2012), as well as Zambian educational policy documents and school context information (Chongwe Municipal Council, 2025; Lusaka Provincial Administration, 2024).

4.2 Demographic and Background Characteristics of Participants

Understanding the demographic and professional background characteristics of participating teachers provides important

context for interpreting their responses and practices. According to Coe et al. (2025), teacher characteristics such as experience, qualifications, and professional development can significantly influence instructional practices and should be considered when analyzing research findings.

4.2.1 Teacher Demographic Profile

The study included 30 mathematics teachers across the three schools. Table 2 presents the demographic characteristics of the teacher participants.

Table 2: Demographic Characteristics of Teacher Participants

Characteristic	Category	Frequency (n = 30)	Percentage (%)
Gender	Male	18	60.0
	Female	12	40.0
Age group	25-34 years	14	46.7
	35-44 years	10	33.3
	45 years	6	20.0
Highest Qualification	Diploma in Education	16	53.3
	Bachelor's Degree	12	40.0
	Master's Degree	2	6.7
Teaching Experience	0-5 years	8	26.7

The demographic data reveal that the majority of mathematics teachers in the three schools are male (60%), with females comprising 40% of the sample. This gender distribution reflects broader patterns in mathematics teaching in Zambian secondary schools, where male teachers tend to predominate in mathematics and science subjects (Ministry of Education, 2023).

In terms of age, nearly half of the teachers (46.7%) are in the 25-34 age range, suggesting a relatively young teaching workforce. This has implications for the adoption of innovative teaching methods, as younger teachers may be more open to new approaches and more familiar with technological tools that support graphical methods. However, as noted by Mashingaidze (2012), experience remains a critical factor in effective mathematics instruction, with experienced teachers developing refined pedagogical strategies over time.

Regarding qualifications, the majority of teachers hold a Diploma in Education (53.3%), while 40% hold a Bachelor's Degree, and a small proportion (6.7%) has attained a Master's

Degree. These qualifications align with the requirements for teaching at the secondary

level in Zambia, where a diploma or degree in education is the standard entry requirement. The presence of teachers with postgraduate qualifications suggests that some teachers have pursued further professional development.

Teaching experience varies across the sample, with the largest group (40%) having 6-10 years of experience. This suggests a balanced distribution between early-career teachers (26.7% with 0-5 years), mid-career teachers (40% with 6-10 years, 20% with 11-15 years), and experienced teachers (13.3% with 16+ years). This diversity in experience levels provides opportunities to explore how experience influences the use of graphical methods in teaching coordinate geometry.

4.2.2 Distribution of Teachers across Schools

The distribution of teacher participants across the three schools is shown in Table 3

Table 3: Distribution of Teacher Participants by School

School	Number of teachers	Percentage (%)
Chainda Secondary School	8	26.7
Chalimbana Secondary School	10	33.3
Chongwe Secondary School	12	40.0
Total	30	100.0

The distribution reflects the relative sizes of the mathematics departments in the three schools. Chongwe Secondary School, as the district's main secondary school, has the largest mathematics department (12 teachers), followed by Chalimbana Secondary School (10 teachers), and Chainda Secondary School (8 teachers). This distribution provides adequate representation from each school for between-school comparisons.

4.2.3 Student Participant Profile

A total of 150 students participated in the questionnaire survey, with 50 students from each of the three schools. Table 4 presents the demographic characteristics of the student participants.

Table 4: Demographic Characteristics of Student Participants

Characteristic	Category	Frequency (n = 150)	Percentage (%)
Gender	Male	78	52.0
	Female	72	48.0
Grade Level	Grade 10	52	34.7
	Grade 11	50	33.3
	Grade 12	48	32.0
School	Chainda SS	50	33.3
	Chalimbana SS	50	33.3
	Chongwe SS	50	33.3

The student sample is approximately balanced in terms of gender (52% male, 48% female) and grade level representation, with students from Grades 10, 11, and 12 comprising roughly equal proportions. The equal distribution across schools (33.3% each) allows for meaningful comparisons of student experiences across the three institutions.

4.3 Graphical Methods Used in Teaching Coordinate Geometry

The first research question sought to identify the graphical methods that mathematics teachers in Chainda, Chalimbana, and Chongwe Secondary Schools use in teaching coordinate geometry. Data from teacher questionnaires, classroom observations, and interviews were analyzed to address this question.

4.3.1 Teacher-Reported Use of Graphical Methods

Teachers were asked to indicate the frequency with which they use various graphical methods when teaching coordinate geometry. Responses were collected on a five-point Likert scale (1 = Never, 2 = rarely, 3 = Sometimes, 4 = Often, 5 = Always). Table 5 presents the mean scores and standard deviations for each method, with methods ordered by frequency of use.

Table 5: Teacher-Reported Frequency of Graphical Methods Used

Graphical method	Mean	SD	Interpretation
Plotting points on the Cartesian plane	4.37	0.67	Often
Drawing graphs of the linear equations	4.23	0.73	Often
Using the chalkboard to draw coordinate systems	4.20	0.81	Often
Employing graph boards and grids	3.90	0.92	Sometimes often
Using real life examples (e.g., maps, navigation)	3.53	1.01	Sometimes
Incorporating visual aids and diagrams in explanations	3.47	0.96	Sometimes
Using transformation geometry activities (translations, reflections)	3.33	1.04	Sometimes
Using coordinate geometry to solve practical problems	3.27	1.10	Sometimes
Using graphing calculators	1.83	0.95	Rarely
Using computer software (e.g., GeoGebra, Demos)	1.67	0.88	Rarely

The data reveal that the most frequently used graphical methods are traditional approaches that rely on manual drawing and plotting. Plotting points on the Cartesian plane (mean = 4.37) and drawing graphs of linear equations (mean = 4.23) are the methods most commonly employed, with teachers reporting that they use these methods "often." Using the chalkboard or whiteboard to draw coordinate systems (mean = 4.20) is also highly frequent, reflecting the continued centrality of board work in Zambian mathematics classrooms.

Graph boards and grids are used with moderate frequency (mean = 3.90), falling between "sometimes" and "often." These physical resources provide structured support for drawing accurate graphs and are available in varying degrees across the three schools. During interviews, teachers at Chongwe Secondary School noted that they have a good supply of graph boards, while teachers at Chainda and Chalimbana reported that these resources are limited and sometimes shared among classes.

Real-life examples (mean = 3.53) and visual aids (mean = 3.47) are used "sometimes," indicating that teachers attempt to connect coordinate geometry to practical contexts and use visual supports to enhance understanding. However, the use of these methods is not consistent across all teachers or lessons. Transformation geometry activities (mean = 3.33) and practical problem-solving (mean = 3.27) are also used "sometimes," with considerable variation among teachers (as indicated

by standard deviations exceeding 1.00). This suggests that while some teachers integrate these approaches, others use them rarely or not at all.

Strikingly, technology-based graphical methods are rarely used. Graphing calculators (mean = 1.83) and computer software such as GeoGebra or Desmos (mean = 1.67) received the lowest scores, with most teachers reporting that they "rarely" or "never" use these tools. This finding is significant given the potential of dynamic geometry software to enhance students' understanding of coordinate geometry concepts (Joswick et al., 2026).

4.3.2 Variations across Schools

Analysis of variance (ANOVA) was conducted to explore whether the use of graphical methods varied significantly across the three schools. Table 6 presents the mean scores for selected methods by school.

The analysis reveals that the only statistically significant difference across schools is in the use of graph boards and grids ($p = 0.046$). Chongwe Secondary School teachers reported using these resources more frequently (mean = 4.17) compared to Chainda (mean = 3.50) and Chalimbana (mean = 3.80). This difference likely reflects variations in resource availability, as Chongwe Secondary School, being the district's main school, may have better access to teaching materials. During interviews, a teacher at Chongwe explained:

Table 6: Mean Frequency of Graphical Methods by School

Graphical method	Chainda ($n = 8$)	Malimbana ($n = 10$)	Chongwe ($n = 12$)	F-value	P-value
Plotting points	4.25	4.30	4.50	1.23	0.307
Drawing linear graphs	4.13	4.20	4.33	0.89	0.421
Graph boards and grids	3.50	3.80	4.17	3.45	0.046
Real-life examples	3.25	3.40	3.83	2.98	0.068
Transformation activities	3.00	3.30	3.58	2.12	0.139
Technology use	1.63	1.70	1.83	0.45	0.642

*Note: $p < 0.05$

"We have a good number of graph boards in the mathematics department. Each teacher can sign one out when teaching coordinate geometry. This makes it easier to demonstrate graphing clearly to students." (Teacher, Chongwe Secondary School)

In contrast, a teacher at Chainda Secondary School noted: "We have only three graph boards for the entire mathematics

department. When several teachers are teaching coordinate geometry at the same time, we have to share or sometimes go without." (Teacher, Chainda Secondary School)

4.3.3 Classroom Observation Findings

Classroom observations of 15 lessons (five per school) provided direct evidence of teachers' use of graphical methods. Table 7 summarizes the observed frequency of different graphical methods across the observed lessons.

Table 7: Observed Frequency of Graphical Methods ($n=15$ lessons)

Graphical method	Observed in lessons	Percentage of lessons
Plotting points on Cartesian plane	14	93.3
Drawing graphs of linear equations	13	86.7
Using chalkboard for coordinate systems	15	100.0
Using graph boards or grids	9	60.0
Incorporating visual aids	8	53.3
Using real-life examples	7	46.7
Transformation geometry activities	6	40.0
Practical problem-solving	5	33.3
Using technology	1	6.7

The observation data largely corroborate the teacher-reported findings. All observed lessons (100%) involved the teacher using the chalkboard or whiteboard to draw coordinate systems. Plotting points was observed in 93.3% of lessons, and drawing

linear graphs in 86.7% of lessons. These traditional methods dominate the observed instruction.

Graph boards or grids were used in 60% of lessons, confirming their moderate but not universal use. When used, teachers

typically employed these resources for demonstrating graphing procedures to the whole class. However, in several observed lessons, teachers noted that the graph boards were not used because they were in use by other classes or because the teacher found them cumbersome to incorporate into the lesson.

Technology use was observed in only one lesson (6.7%), where a teacher at Chongwe Secondary School used a graphing calculator to demonstrate how changing parameters affects the shape of a quadratic graph. This teacher, who had recently attended a professional development workshop on technology integration, explained:

"I learned about using the graphing calculator at a workshop last year. I try to use it when possible, but we have only two calculators for the whole department, so it's not something I can do regularly." (Teacher, Chongwe Secondary School)

The observation data also revealed qualitative differences in how graphical methods were implemented. In lessons where teachers used multiple graphical approaches, students appeared more engaged and asked more questions. For example, in a lesson at Chalimbana Secondary School where the teacher used board drawing and a real-life example (mapping distances in the local area), students actively participated in identifying coordinates and calculating distances.

4.3.4 Qualitative Insights on Graphical Methods

Interview data provided deeper insights into teachers' understanding and use of graphical methods. Several themes emerged from the analysis of interview transcripts.

Understanding of Graphical Methods

Teachers generally conceptualized graphical methods as approaches that involve visual representations of mathematical relationships. As one teacher explained: "Graphical methods mean showing students the visual side of coordinate geometry. Instead of just giving formulas, you show them how the points connect to make lines and shapes." (Teacher, Chalimbana Secondary School)

However, some teachers had a more limited conception, equating graphical methods primarily with drawing graphs on the board. A teacher at Chainda noted:

"I use graphical methods when I draw the axes and plot points. That's the main way I teach coordinate geometry—by drawing on the board." (Teacher, Chainda Secondary School) This limited conception may constrain teachers' use of the full range

of graphical approaches available, including dynamic representations and real-world applications.

Rationale for Method Selection

Teachers described various reasons for choosing particular graphical methods. The most commonly cited factors were:

Clarity and Visibility: Teachers emphasized the importance of methods that enable all students to see and follow the demonstration. A teacher at Chongwe explained:

"When I use the board to draw, I make sure the grid is large and clear so students at the back can see. If I used a graph board, it's smaller and some students struggle to see." (Teacher, Chongwe Secondary School)

Alignment with Curriculum Requirements: Teachers noted that some methods align more directly with examination expectations. A teacher at Chalimbana observed:

"The exams require students to draw graphs and plot points accurately. So I focus on those skills. The practical examples are good, but they don't appear directly in exams." (Teacher, Chalimbana Secondary School) **Student Prior Knowledge:** Teachers considered students' existing mathematical understanding when selecting methods. An experienced teacher at Chongwe explained:

"With students who are struggling, I use more concrete methods—plotting each point step by step, using graph paper so they can see exactly where points go. For stronger students, I move to more abstract discussions." (Teacher, Chongwe Secondary School)

Challenges with Advanced Graphical Methods

Teachers identified significant challenges in implementing more advanced graphical methods, particularly those involving technology. The most frequently mentioned challenges were:

- Lack of equipment: Limited availability of graphing calculators and computers
- Insufficient training: Lack of familiarity with mathematical software
- Curriculum pressures: Time constraints that discourage experimentation with new methods
- Student preparedness: Concerns that students lack the prerequisite skills to benefit from advanced methods

One teacher captured these challenges succinctly:

"I would like to use GeoGebra to show transformations dynamically, but we don't have computers in the classroom.

Even if we did, I'm not confident I could use it effectively. I need training and practice first." (Teacher, Chainda Secondary School)

4.3.5 Summary of Graphical Methods Used

The findings on graphical methods used in teaching coordinate geometry reveal several key patterns:

1. Traditional manual methods (plotting points, drawing graphs, board work) are used most frequently and consistently across all three schools.
2. Graph boards and grids are used with moderate frequency, with significant variation based on resource availability.
3. Real-life examples, transformation activities, and practical problem-solving are used occasionally but not consistently.
4. Technology-based methods (graphing calculators, computer software) are rarely used due to resource limitations and training gaps.
5. Teachers' conceptions of graphical methods are often limited to manual drawing, potentially restricting the range of approaches they employ.

These findings align with Mashingaidze's (2012) observation that teachers in resource-constrained contexts tend to rely on traditional instructional approaches that require minimal equipment and preparation. However, they also highlight opportunities for expanding teachers' repertoires through professional development and resource provision.

4.4 Frequency of Graphical Methods in Coordinate Geometry Instruction

The second research question addressed the frequency with which different graphical methods are employed in coordinate geometry instruction. This section presents both quantitative and qualitative data on the regularity and timing of graphical method use.

4.4.1 Overall Frequency Patterns

As presented in Table 8, the overall frequency of graphical method use varies considerably across methods. To provide a more complete picture of frequency, teachers were asked to indicate how often they incorporate graphical methods in their coordinate geometry teaching overall, regardless of the specific method. Figure 8 presents the distribution of responses.

Table 8: Overall Frequency of Graphical Method Use

Frequency Category	Percentage of Teachers (%)
Always (in every lesson)	13.3
Often (in most lessons)	36.7
Sometimes (in about half of lessons)	33.3
Rarely (in few lessons)	13.3
Never	3.3

The data show that 50% of teachers report using graphical methods "often" or "always" in their coordinate geometry instruction, while 33.3% uses them "sometimes." A notable minority (16.6%) use graphical methods "rarely" or "never." This indicates that while graphical methods are a regular part of instruction for many teachers, they are not universally or consistently employed.

4.4.2 Frequency by Topic within Coordinate Geometry

Teachers were asked to indicate how frequently they use graphical methods when teaching specific topics within coordinate geometry. Table 9 presents the mean frequency scores for different topics.

Table 9: Frequency of Graphical Method Use by Topic

Topic	Mean frequency	SD	Interpretation
Plotting points and reading coordinates	4.50	0.63	Often
Distance between two points	3.97	0.85	Often
Mid-point of a line segment	3.90	0.88	Sometimes- often
Gradient of a straight line	4.13	0.78	Often
Equation of a straight line	4.27	0.74	Often
Parallel and perpendicular lines	3.83	0.91	Sometimes-often
Transformations (translations, reflections)	3.33	1.03	Sometimes
Coordinate geometry application	3.20	1.07	Sometimes
Circles and curves	2.83	1.12	Sometimes

The data reveal that graphical methods are used most frequently for foundational topics such as plotting points (mean = 4.50), equations of straight lines (mean = 4.27), and gradient (mean = 4.13). These topics naturally lend themselves to graphical representation and are typically taught early in the coordinate geometry sequence.

For more advanced topics such as transformations (mean = 3.33) and applications (mean = 3.20), graphical methods are used less frequently. Circles and other curves (mean = 2.83) receive the lowest frequency, with teachers reporting that they use graphical methods "sometimes" or even "rarely" for this content.

A teacher at Chalimbana explained the difference in frequency: "For straight lines, you can't teach without graphs. The whole idea of gradient and intercept comes from the graph. But for circles, it's more formula-based. You can draw them, but it takes time and students often find it difficult to draw circles accurately." (Teacher, Chalimbana Secondary School)

4.4.3 Frequency by Grade Level Teachers were asked about how the frequency of graphical method use varies across grade levels. Table 10 presents the mean frequency scores for different grade levels.

Table 10: Frequency of Graphical Method Use by Grade Level

Grade level	Mean frequency	SD	interpretation
Grade 10	4.17	0.79	Often
Grade 11	3.93	0.88	Often
Grade 12	3.67	0.95	Sometimes-often

The data show a decreasing trend in the use of graphical methods as students' progress through the secondary grades. Graphical methods are used most frequently in Grade 10 (mean = 4.17), where coordinate geometry is typically introduced. Frequency decreases in Grade 11 (mean = 3.93) and further in Grade 12 (mean = 3.67).

This pattern reflects the curriculum structure, where coordinate geometry concepts become more advanced and abstract in higher grades. As one teacher explained:

"In Grade 10, we are building the foundation. Students need to see the graphs, plot points, understand what coordinates mean. By Grade 12, we assume they know these basics, and we focus more on applications and problem-solving, which may involve less drawing." (Teacher, Chongwe Secondary School)

However, some teachers expressed concern that decreasing use of graphical methods in higher grades might be problematic. An experienced teacher noted:

"Even in Grade 12, some students still struggle with graphs. If we reduce graphical work too much, they don't get the practice they need. The concepts are more complex, but the graphical foundation is still important." (Teacher, Chainda Secondary School)

4.4.4 Frequency of Technology Use

Given the low reported use of technology-based graphical methods, further analysis was conducted to understand the frequency of technology use across schools and teacher characteristics. Table 11 presents the frequency of technology use by teacher experience level.

Table 11: Frequency of Technology Use by Teaching Experience

Experience level	Mean frequency	SD	n
0-5 years	2.13	0.83	8
6-10 years	1.67	0.65	12
11-15 years	1.50	0.55	6
16+years	1.25	0.50	4

The data suggest that early-career teachers (0-5 years' experience) report slightly higher use of technology-based graphical methods (mean = 2.13) compared to more experienced teachers. This may reflect greater familiarity with technology among younger teachers who completed their training more recently.

However, even among early-career teachers, the frequency remains low, with most reporting that they use technology "rarely." During interviews, early-career teachers explained that while they were exposed to mathematical software during their training, they lack access to the required equipment in their schools.

4.4.5 Qualitative Insights on Frequency

Interview data provided additional context for understanding the frequency patterns observed. Several factors emerged as influences on how often teachers use graphical methods. Time Constraints

Time was frequently cited as a factor limiting the frequency of graphical method use. Teachers noted that drawing accurate graphs takes time, and curriculum coverage pressures sometimes lead them to prioritize faster, more direct instructional approaches.

"If I draw every graph carefully, showing all the steps, I lose time for covering other topics. Sometimes I have to move faster and just explain the concept without drawing everything." (Teacher, Chainda Secondary School)

Resource Availability

As noted earlier, the availability of graph boards and other resources influences frequency. Teachers with ready access to resources reported using them more frequently.

Student Engagement

Some teachers reported that they use graphical methods more frequently when they observe positive student responses. A teacher at Chongwe explained:

"When I use graphs, students are more interested. They like to see the visual representation. So I try to include graphical work even when it's not strictly necessary, because it helps keep them engaged." (Teacher, Chongwe Secondary School)

Examination Preparation

The pressure to prepare students for examinations was another factor influencing frequency. Teachers noted that since examinations require students to draw and interpret graphs, they prioritize graphical methods for topics likely to appear in exams.

4.4.6 Summary of Frequency Findings

The findings on frequency of graphical method use indicate:

1. Approximately half of teachers use graphical methods "often" or "always" in their coordinate geometry instruction, while a significant minority uses them less consistently.
2. Graphical methods are used most frequently for foundational topics (plotting points, equations of straight lines) and less frequently for advanced topics (transformations, circles, applications).
3. Use of graphical methods decreases as students' progress through grade levels, with highest frequency in Grade 10 and lowest in Grade 12.
4. Technology-based graphical methods are used rarely across all schools and teacher experience levels.
5. Time constraints, resource availability, student engagement, and examination preparation all influence the frequency of graphical method use.

These frequency patterns have implications for student learning, as consistent exposure to graphical representations is important for developing conceptual understanding of coordinate geometry (Mashingaidze, 2012).

4.5 Factors Influencing Teachers' Selection and Use of Graphical Methods

The third research question explored the factors that influence teachers' selection and use of graphical methods in teaching coordinate geometry. Data from teacher questionnaires and interviews were analyzed to identify the key factors shaping instructional decisions.

4.5.1 Teacher-Reported Influences

Teachers rated the extent to which various factors influenced their use of graphical methods on a five-point scale (1 = Not at all influential, 2 = slightly influential, 3 = moderately influential, 4 = Very influential, 5 = extremely influential). Table 12 presents the mean influence scores for each factor.

Table 12: Factors Influencing Use of Graphical Methods

Factor	Mean	SD	Interpretation
Curriculum requirements and syllabus guidance	4.53	0.63	Very-extremely influential
Student background and prior knowledge	4.40	0.72	Very influential
Assessment demands and examination preparation	4.33	0.76	Very influential
Time constraints and lesson pacing	3.87	0.86	Very influential

Personal beliefs about mathematics teaching	3.70	0.92	Moderately- very influential
Class size and classroom conditions	3.53	0.94	Moderately-very influential
Teacher training and professional development	3.47	0.97	Moderately influential
Availability of resources and teaching materials	4.07	0.83	Very influential

The data reveal that curriculum requirements (mean = 4.53) are the most influential factor shaping teachers' use of graphical methods. Teachers are guided by the syllabus requirements for teaching coordinate geometry, which specify the graphical skills students must develop.

Student background and prior knowledge (mean = 4.40) and assessment demands (mean = 4.33) are also highly influential. Teachers consider what students already know and what they will be expected to demonstrate in examinations when deciding how to teach.

Resource availability (mean = 4.07) is rated as "very influential," confirming the importance of access to graph boards, graph paper, and other materials. Time constraints (mean

= 3.87) and personal beliefs (mean = 3.70) have moderate to strong influence, while class size (mean = 3.53) and teacher training (mean = 3.47) have moderate influence.

4.5.2 Curriculum and Syllabus Influence

The strong influence of curriculum requirements was evident across all data sources. Teachers described the Zambian mathematics syllabus as providing clear guidance on what should be taught and how.

"The syllabus tells us that students should be able to plot points, draw graphs, and find gradients, and so on. So I make sure I cover these things. The graphical methods I use are the ones that help students achieve these syllabus objectives." (Teacher, Chongwe Secondary School)

However, some teachers noted that the syllabus focuses more on content than on pedagogical approaches. A teacher at Chalimbana explained:

"The syllabus tells us what to teach but not necessarily how to teach it. So there is flexibility, but also uncertainty. Sometimes I'm not sure if I'm using the best methods because the syllabus

doesn't give that guidance." (Teacher, Chalimbana Secondary School)

This observation highlights an opportunity for curriculum materials to provide more explicit guidance on pedagogical approaches, particularly for topics like coordinate geometry where graphical methods are essential.

4.5.3 Student Factors

Student-related factors emerged as significant influences on teachers' method selection. Teachers considered students' prior knowledge, learning needs, and responses to different approaches.

Prior Knowledge and Preparedness

Teachers noted that students' mathematical background varies considerably, affecting how they respond to graphical methods. A teacher at Chainda observed:

"Some students come to secondary school having done some coordinate geometry in primary. Others have never seen a graph before. I have to adjust my methods based on what they know." (Teacher, Chainda Secondary School)

Learning Difficulties

Teachers described specific difficulties students experience with coordinate geometry, which influence their choice of methods. Common difficulties included:

- Understanding negative coordinates
 - Accurately plotting points
 - Interpreting graphs (e.g., what the gradient represents)
 - Moving between algebraic and graphical representations
- "When students struggle with negative coordinates, I spend more time on the graphical side. I draw many examples, use different colors to show positive and negative axes, and have them practice plotting points on graph paper." (Teacher, Chalimbana Secondary School)

Student Engagement

Teachers noted that graphical methods tend to increase student engagement, which encourages continued use of these approaches.

"Students get excited when they see the graph taking shape. They want to see if they plotted points correctly. That engagement is valuable, so I try to use graphs even when it takes more time." (Teacher, Chongwe Secondary School)

4.5.4 Resource Availability

Resource availability was a consistently mentioned factor across all three schools.

Teachers identified several resource-related challenges:

Graph Boards and Grids

As noted in Section 4.3.2, the availability of graph boards varies across schools. Where resources are limited, teachers report using graphical methods less frequently or relying on less effective alternatives.

"When I don't have a graph board, I have to draw axes freehand on the board. It's not as accurate, and it takes longer. Students can see it's not perfect, and that sometimes confuses them." (Teacher, Chainda Secondary School)

Graph Paper

Access to graph paper was another resource issue. Some schools provide graph paper to students, while in others; students are expected to purchase their own.

"We try to provide graph paper for students, but sometimes supplies run out. When students don't have graph paper, they draw on ordinary paper, which makes it harder to be accurate." (Teacher, Chalimbana Secondary School)

Technology Resources

The absence of technology resources (graphing calculators, computers, and projectors) was identified as a major barrier to using more advanced graphical methods.

"I know there are programs that can show graphs moving as you change numbers. That would be so helpful for teaching transformations. But we don't have computers or projectors. It's just me and the board." (Teacher, Chongwe Secondary School)

4.5.5 Time Constraints

Time pressures were identified as significant factors influencing teachers' method selection. Teachers must balance

the need for thorough graphical instruction with the demands of covering the full curriculum.

"The coordinate geometry unit is supposed to take about three weeks. But with all the topics to cover—plotting, distance, midpoint, gradient, equations, transformations—three weeks is not enough if you're going to do full graphical work for everything." (Teacher, Chainda Secondary School)

To manage time constraints, teachers reported sometimes taking shortcuts:

- Using pre-drawn graphs rather than having students draw their own
- Focusing on algebraic methods for some topics
- Combining topics to save time

4.5.6 Personal Beliefs and Training

Teachers' personal beliefs about mathematics teaching and their professional training also influenced method selection.

Beliefs about Mathematics Teaching

Teachers with constructivist beliefs about learning tended to use more varied graphical methods, including hands-on activities and real-life examples. Teachers with more transmission-oriented beliefs tended to rely more on demonstration and practice.

"I believe students learn mathematics by doing, not just watching. So I try to have them plot points themselves, draw their own graphs, and discover patterns. That takes more time but leads to better understanding." (Teacher, Chongwe Secondary School)

Training Experiences

Teachers who had received specific training in teaching coordinate geometry or using graphical methods reported greater confidence and variety in their approaches.

"In my teacher training, we spent time learning how to use different methods for coordinate geometry. That gave me a toolkit I can draw from. Without that training, I might just use the same approach for everything." (Teacher, Chalimbana Secondary School)

However, several teachers noted that their pre-service training did not adequately prepare them for the realities of teaching in Zambian secondary schools, particularly regarding resource constraints.

4.5.7 Summary of Influencing Factors

The findings on factors influencing teachers' use of graphical methods reveal:

1. Curriculum requirements and assessment demands are the most influential factors, guiding what teachers teach and how they teach it.
2. Student background and prior knowledge significantly influence teachers' method selection, as teachers adapt to their students' needs.
3. Resource availability, particularly of graph boards and graph paper, affects both the frequency and quality of graphical method use.
4. Time constraints create pressures that sometimes lead teachers to reduce or simplify graphical work.
5. Personal beliefs about mathematics teaching and professional training influence the variety and innovation of approaches used.

These factors interact in complex ways to shape teachers' instructional decisions. For example, a teacher with strong constructivist beliefs (personal factor) might want to use

diverse graphical methods but be constrained by limited resources (resource factor) and time pressures (contextual factor).

4.6 Challenges Teachers Encounter When Using Graphical Methods

The fourth research question examined the challenges teachers face when using graphical methods to teach coordinate geometry. Data from teacher questionnaires, interviews, and classroom observations were analyzed to identify and understand these challenges.

4.6.1 Teacher-Reported Challenges

Teachers were asked to identify and rate the challenges they encounter when using graphical methods. Table 13 presents the mean challenge scores for different types of challenges (1 = Not a challenge, 2 = Minor challenge, 3 = Moderate challenge, 4 = Major challenge, 5 = Severe challenge).

Table 13: Challenges in Using Graphical Methods

Challenge Category	Mean	SD	Interpretation
Insufficient resources and materials	4.27	0.74	Major to Severe challenge
Time constraints	4.03	0.81	Major challenge
Large class sizes	3.90	0.88	Major challenge
Students' weak mathematical foundation	3.83	0.91	Major challenge
Lack of appropriate technology	3.80	0.96	Major challenge
Inadequate teacher training	3.53	0.97	Moderate to Major challenge
Curriculum demands	3.47	0.94	Moderate-Major challenge
Assessment methods not aligning with graphical work	3.27	1.01	Moderate challenge

The data reveal that resource shortages (mean = 4.27) are the most severe challenge teachers face when using graphical methods. This finding is consistent with earlier observations about limited availability of graph boards, graph paper, and technology resources.

Time constraints (mean = 4.03) and large class sizes (mean = 3.90) are also rated as major challenges. These contextual factors affect teachers' ability to provide individualized attention and to conduct hands-on graphical activities.

Students' weak mathematical foundation (mean = 3.83) and lack of appropriate technology (mean = 3.80) are also significant challenges. Teachers noted that many students struggle with basic concepts such as positive and negative numbers, making it difficult to teach coordinate geometry effectively.

Inadequate teacher training (mean = 3.53) and curriculum demands (mean = 3.47) are rated as moderate to major challenges, while assessment methods not aligning with

graphical work (mean = 3.27) is considered a moderate challenge.

4.6.2 Resource-Related Challenges

Resource challenges were the most frequently mentioned in interviews and observations. These challenges took several forms:

Insufficient Graph Boards

As noted earlier, the limited number of graph boards was a recurring concern. Teachers described the impact of this shortage:

"With only three graph boards for eight teachers, you can't always have one when you need it. So sometimes you teach without, or you use a board that's been worn down and the lines are faded." (Teacher, Chainda Secondary School)

Shortage of Graph Paper

The availability of graph paper for students was another resource challenge. Teachers explained:

"When students don't have graph paper, they draw on notebook paper. Their graphs are not accurate because they don't have a proper grid. This leads to errors that aren't really their fault." (Teacher, Chalimbana Secondary School)

Lack of Technology

The absence of technology resources was described as limiting teachers' ability to demonstrate dynamic graphical concepts:

"With software like GeoGebra, I could show how a graph changes when you change the gradient or intercept. Students could see it moving. But we don't have that here. It's all static drawing." (Teacher, Chongwe Secondary School)

4.6.3 Time-Related Challenges

Time pressures emerged as a significant challenge, affecting both the quality and frequency of graphical work.

Curriculum Coverage Pressures

Teachers described the tension between spending adequate time on graphical methods and covering all required content:

"The syllabus expects us to cover so much. If I spend time having students draw accurate graphs, I fall behind. So sometimes I rush through graphical work just to keep up with the pace." (Teacher, Chainda Secondary School)

Time for Drawing

The mechanical aspects of drawing graphs take considerable time, particularly when students are learning:

"Drawing a graph properly takes time. Students need to label axes, choose scales, plot points accurately. When you have 50 students in a class, moving through these steps with everyone takes the whole period for just one graph." (Teacher, Chalimbana Secondary School)

4.6.4 Class Size Challenges

Large class sizes were identified as a major challenge that affects graphical instruction in several ways:

Individual Attention

Teachers noted difficulty providing individual support during graphical activities: "When I have 50 students, I cannot check every graph they draw. Some students make mistakes that go unnoticed. They continue practicing incorrectly and develop bad habits." (Teacher, Chongwe Secondary School)

Visibility

Ensuring all students can see demonstrations is challenging in large classes:

"I stand at the board and draw, but students at the back cannot see clearly. If I use a graph board, it's even smaller. Some students just give up and stop paying attention." (Teacher, Chainda Secondary School)

Classroom Management

Managing hands-on graphical activities with large classes presents management challenges:

"When I give students graph paper and ask them to plot points, the noise level increases. Some students do the work, others just talk. It's hard to maintain focus with so many students." (Teacher, Chalimbana Secondary School)

4.6.5 Student-Related Challenges

Teachers described various challenges related to students' mathematical background and learning needs.

Weak Foundational Knowledge

Many students lack prerequisite knowledge needed for coordinate geometry: "Students come to me in Grade 10 not knowing how to work with negative numbers."

When I ask them to plot $(-3, -2)$, they are confused. I have to teach basic number concepts before I can teach coordinate geometry." (Teacher, Chongwe Secondary School)

Difficulties with Abstract Thinking

Some students struggle with the abstract nature of graphical representations:

"For some students, the connection between an equation and a graph is not obvious. They can plot points by following steps, but they don't understand what the graph represents. It's just lines on paper to them." (Teacher, Chainda Secondary School)

Language Barriers

In some cases, language presents challenges, particularly for students who are not comfortable with English, the medium of instruction:

"When I explain graphical concepts, I use mathematical language. Some students don't fully understand the terms. This makes it harder for them to grasp what I'm trying to show." (Teacher, Chalimbana Secondary School)

4.6.6 Teacher Training and Professional Development Challenges

Teachers identified gaps in their preparation for teaching coordinate geometry with graphical methods.

Inadequate Pre-Service Training

Several teachers felt their initial training did not adequately prepare them:

"In college, we learned about coordinate geometry theoretically. We didn't have much practice teaching it or using different graphical methods. When I started teaching, I had to figure out a lot on my own." (Teacher, Chalimbana Secondary School)

Limited In-Service Opportunities

Teachers noted a lack of ongoing professional development opportunities focused on mathematics instruction:

"There are workshops sometimes, but not often focused on mathematics. When there is a workshop, it's usually about general teaching methods or administrative issues. We need specific training on teaching coordinate geometry effectively." (Teacher, Chongwe Secondary School)

Lack of Peer Support

Some teachers described working in isolation without opportunities to learn from colleagues: "We have other mathematics teachers, but we don't often observe each other or share ideas. Everyone does their own thing. I would like to see how others use graphical methods, but that doesn't happen." (Teacher, Chainda Secondary School)

4.6.7 Summary of Challenges

The findings on challenges teachers encounter when using graphical methods reveal:

1. Resource shortages, particularly of graph boards, graph paper, and technology, are the most severe challenge across all three schools.
2. Time constraints create significant pressure, leading teachers to reduce or rush graphical work.
3. Large class sizes impede individual attention, visibility, and classroom management during graphical activities.
4. Students' weak foundational knowledge in mathematics presents ongoing challenges for teaching coordinate geometry.
5. Inadequate teacher training and limited professional development opportunities leave teachers without the preparation and support they need.

These challenges are interconnected and systemic; suggesting that addressing them will require coordinated efforts at multiple levels—from resource provision to curriculum design to professional development.

4.7 Student Responses and Engagement with Graphical Methods

The fifth research question explored how students respond to and engage with graphical methods in coordinate geometry lessons. Data from student questionnaires and focus groups were analyzed to understand student perspectives on graphical instruction.

4.7.1 Student Perceptions of Graphical Methods

Students were asked to rate their agreement with statements about graphical methods on a five-point scale (1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree). Table 14 presents the mean scores for each statement.

Table 14: Student Perceptions of Graphical Methods

Statement	Mean	SD	Interpretation
Graphical methods help me understand coordinate geometry better	4.13	0.82	Agree
I enjoy lessons where my teacher uses graphs and diagrams	4.07	0.85	Agree
Drawing graphs makes coordinate geometry more interesting	3.97	0.88	Agree
I can see how coordinate geometry applies to real life when graphs are used	3.87	0.91	Agree
I find it easier to solve problems when I can use a graph	3.83	0.94	Agree
I prefer when my teacher focuses on formulas rather than graphs	3.70	1.02	Neutral-agree
Using graphs is sometimes confusing	2.90	1.07	Neutral
Graphs make coordinate geometry more difficult to understand	2.73	1.03	Disagree

The data reveal that students generally hold positive perceptions of graphical methods. Students agree that graphical methods help them understand coordinate geometry better (mean = 4.13) and that they enjoy lessons where teachers use graphs and diagrams (mean = 4.07). They also agree that drawing graphs makes coordinate geometry more interesting (mean = 3.97) and helps them see real-life applications (mean = 3.87).

The statement "Using graphs is sometimes confusing" received a mean of 3.70, indicating moderate agreement. This suggests that while students value graphical methods, they also experience some confusion, particularly when learning to interpret graphs or when graphs are drawn inaccurately.

Students disagreed with the statement that graphs make coordinate geometry more difficult to understand (mean = 2.73) and were neutral about preferring formulas over graphs (mean = 2.90). This indicates that, overall, students do not view graphical methods as a source of difficulty and do not strongly prefer algebraic approaches.

4.7.2 Variations in Student Perceptions by Grade Level
Student perceptions were analyzed by grade level to explore whether attitudes toward graphical methods change as students' progress. Table 15 presents the mean scores for key statements by grade level.

Table 15: Student Perceptions by Grade Level

Statement	Grade 10 (n=52)	Grade 11 (n=50)	Grade 12 (n=48)	F-value	p-value
Graphical methods help understanding	4.25	4.10	4.02	2.45	0.089
I enjoy lessons with graphs	4.21	4.04	3.96	2.78	0.065
Graphs make coordinate geometry interesting	4.12	3.94	3.85	2.93	0.057
Graphs are sometimes confusing	3.58	3.72	3.81	1.84	0.162

While the differences are not statistically significant at the $p < 0.05$ level, there are trends suggesting that positive perceptions of graphical methods are strongest in Grade 10 and decrease

somewhat in higher grades. This pattern aligns with the finding that teachers use graphical methods less frequently in higher

grades, which may affect students' continued engagement with these approaches.

4.7.3 Focus Group Findings

Focus group discussions provided rich qualitative data on students' experiences with graphical methods. Several themes emerged from the analysis.

Appreciation of Visual Learning

Students expressed appreciation for the visual nature of graphical methods. A Grade 10 student at Chongwe explained: "When the teacher draws the graph, I can see what the numbers mean. Just looking at the equation, it's hard to imagine what it looks like. But when I see the line on the graph, it makes sense." (Student, Chongwe Secondary School)

Another student at Chainda noted:

"I like when we draw graphs because it's visual. I'm a visual learner. When I can see the points and the lines, I remember better than when I just memorize formulas." (Student, Chainda Secondary School)

Engagement through Participation

Students reported being more engaged when they actively participated in graphical activities:

"When the teacher gives us graph paper and we plot points ourselves, I pay more attention. If the teacher just draws on the board, sometimes I get bored. But when I'm drawing, I'm involved." (Student, Chalimbana Secondary School)

Understanding the "Why" Behind Formulas

Several students noted that graphical methods helped them understand the reasoning behind mathematical formulas:

"I used to just memorize the distance formula. But when the teacher showed us how it comes from the graph—the right triangle—I understood why the formula works. Now I don't have to just memorize." (Student, Grade 11, Chongwe Secondary School)

Difficulties with Accuracy

Students also described challenges they experience with graphical methods, particularly related to accuracy:

"I find it difficult to draw graphs accurately. When I plot points, sometimes they are slightly off. Then when I draw the line, it doesn't look right. That's frustrating." (Student, Grade 10, Chainda Secondary School)

Another student added:

"If my graph paper doesn't have clear lines, or if I don't have a ruler, my graph is not accurate. Then I get the wrong answer even if I understood the concept." (Student, Grade 11, Chalimbana Secondary School)

Support from Teachers

Students appreciated when teachers provided support and feedback during graphical work:

"Our teacher walks around and looks at our graphs. If we make a mistake, she helps us see what went wrong. That helps me learn because I can correct my errors." (Student, Grade 12, Chongwe Secondary School)

Requests for More Practice

Students expressed desire for more opportunities to practice graphical methods: "We don't always get enough time to draw graphs. The teacher sometimes moves on quickly because there is a lot to cover. I wish we had more time to practice so I can get better at drawing accurately." (Student, Grade 10, Chainda Secondary School)

4.7.4 Gender Differences in Student Perceptions

Analysis of student questionnaire data revealed some gender differences in perceptions of graphical methods. Table 16 presents mean scores by gender for selected statements.

Table 16: Student Perceptions by Gender

Statement	Male (n=78)	Female (n=72)	t-value	p-value
Graphical methods help understanding	4.08	4.18	-0.72	0.473
I enjoy lessons with graphs	4.03	4.11	-0.58	0.563
Graphs are sometimes confusing	3.67	3.74	-0.45	0.653
I prefer formulas over graphs	2.95	2.85	0.62	0.536

No statistically significant gender differences were found in students' perceptions of graphical methods. Both male and female students reported similarly positive views and similar levels of confusion. This finding suggests that graphical methods are equally accessible and appealing to both genders, at least in terms of students' reported perceptions.

4.7.5 Summary of Student Responses

The findings on student responses and engagement with graphical methods reveal:

1. Students generally hold positive perceptions of graphical methods, agreeing that these approaches help understanding and make learning more interesting.
2. Students appreciate the visual nature of graphical methods and report being more engaged when they actively participate in graphical activities.
3. Graphical methods help students understand the reasoning behind formulas, supporting conceptual understanding rather than mere memorization.
4. Students experience challenges with accuracy in drawing graphs, particularly when resources are inadequate.
5. Students desire more opportunities for practice and individualized support during graphical activities.

6. No significant gender differences were found in student perceptions of graphical methods.

These findings highlight the value students place on graphical methods and suggest that increasing the frequency and quality of graphical instruction could enhance student learning and engagement.

4.8 Integration of Findings across Schools

This section integrates findings across the three schools to identify patterns and differences in teachers' use of graphical methods in teaching coordinate geometry.

4.8.1 Between-School Comparisons

Dimension	Chainda SS	Chalimbana SS	Chongwe SS
Teacher characteristics	8 teachers, mixed Experience levels	10 teachers, balanced distribution	12 teachers, more experienced
Resource availability	Limited graph boards, graph paper sometimes available	Some graph boards, graph paper inconsistent	Better resources, more graph boards available
Frequency of graphical methods	Moderate use, limited technology	Moderate limited technology	More frequent use, some technology use
Most used methods	Plotting, drawing, board work	Plotting, drawing, board work	Plotting, drawing, board work, some real-life examples

While there are many similarities across the three schools, several differences are noteworthy:

Resource Availability: Chongwe Secondary School appears to have better access to resources, particularly graph boards and graph paper, compared to Chainda and Chalimbana. This likely reflects its status as the district's main secondary school and potentially greater investment in its mathematics department.

Technology Use: Chongwe reported slightly higher use of technology, with one teacher having attended a workshop on graphing calculators. This suggests that opportunities for professional development can influence practice, even in resource-constrained contexts.

Student Engagement: Students at Chongwe reported somewhat higher engagement with graphical methods, which may be related to the greater variety of methods used and the better resources available.

4.8.2 Common Patterns across Schools

Despite differences in specific contexts, several patterns were consistent across all three schools:

1. **Dominance of Traditional Methods:** In all schools, traditional manual methods (plotting points, drawing graphs, board work) dominate instruction.
2. **Rare Technology Use:** Technology-based graphical methods are rarely used in any of the schools, despite recognition of their potential value.
3. **Resource Constraints:** All schools face resource challenges that affect the quality and frequency of graphical instruction.
4. **Time Pressures:** Curriculum coverage demands create time pressures that lead to reduced or rushed graphical work in all schools.

5. Student Appreciation: Students across all schools expressed appreciation for graphical methods and reported that these approaches help their understanding.

4.8.3 Contextual Factors

The findings suggest that contextual factors play important roles in shaping teachers' use of graphical methods. These factors include:

School Location and History: Chongwe Secondary School's location in the district town and its history as a long-established school appear to provide some advantages in terms of resources and teacher experience.

Recent Infrastructure Development: Chalimbana Secondary School has recently benefited from new classroom construction (Lusaka Provincial Administration, 2024), which has improved the physical learning environment. However, this development has not yet translated into enhanced resources for graphical instruction.

Leadership and Departmental Culture: Differences in leadership and departmental culture may influence the priority given to mathematics resources and professional development. These factors warrant further investigation.

4.9 Summary of Findings

This chapter has presented and analyzed data on teachers' use of graphical methods in teaching coordinate geometry in three secondary schools in Chongwe District. The key findings are summarized below:

4.9.1 Graphical Methods Used

Mathematics teachers in the three schools use a range of graphical methods, with traditional manual approaches being most common. Plotting points on the Cartesian plane, drawing graphs of linear equations, and using the chalkboard or whiteboard to draw coordinate systems are used most frequently. Graph boards and grids are used with moderate frequency, while real-life examples, transformation activities, and practical problem-solving are used occasionally. Technology-based methods such as graphing calculators and computer software are rarely used.

4.9.2 Frequency of Use

Approximately half of teachers use graphical methods "often" or "always" in their coordinate geometry instruction. Graphical methods are used most frequently for foundational topics and

in lower grades (Grade 10), with frequency decreasing for advanced topics and in

higher grades. Technology-based methods are used rarely across all schools and teacher experience levels.

4.9.3 Influencing Factors

Curriculum requirements and assessment demands are the most influential factors shaping teachers' use of graphical methods. Student background and prior knowledge, resource availability, and time constraints also significantly influence method selection. Personal beliefs about mathematics teaching and professional training play important but secondary roles.

4.9.4 Challenges

Resource shortages, particularly of graph boards, graph paper, and technology, are the most severe challenge teachers face. Time constraints, large class sizes, students' weak mathematical foundation, and inadequate teacher training also present significant challenges that affect the quality and frequency of graphical instruction.

4.9.5 Student Responses

Students generally hold positive perceptions of graphical methods, agreeing that these approaches help understanding, make learning more interesting, and help them see real-life applications. Students appreciate the visual nature of graphical methods and report being more engaged when they actively participate in graphical activities. However, students also experience challenges with accuracy and desire more opportunities for practice and support.

4.9.6 Between-School Patterns

While there are many similarities across the three schools, Chongwe Secondary School appears to have some advantages in terms of resource availability and professional development opportunities, which correspond to somewhat more frequent and varied use of graphical methods. All schools face significant challenges related to resources, time, and class size that constrain the use of graphical methods.

4.10 Interpretation of Findings

The findings presented in this chapter are interpreted in light of existing literature on mathematics education and the Zambian educational context.

4.10.1 Alignment with Existing Research

The dominance of traditional manual methods in teaching coordinate geometry aligns with findings from other studies in resource-constrained contexts. Mashingaidze (2012) observed similar patterns in his study of geometric transformations, noting that teachers tend to rely on approaches that require minimal equipment and preparation. The limited use of technology-based graphical methods is consistent with broader findings on technology integration in Zambian schools, where infrastructure and equipment shortages remain significant barriers (Ministry of Education, 2023).

The positive student responses to graphical methods align with research on the effectiveness of visual representations in mathematics learning. Joswick et al. (2026) demonstrated that carefully designed graphical routines can enhance student engagement and conceptual understanding. The present study confirms that students value graphical approaches and perceive them as helpful for understanding coordinate geometry.

4.10.2 Implications for Teacher Practice

The findings have several implications for teacher practice:

Expanding Repertoires: While traditional manual methods are valuable, expanding teachers' repertoires to include more varied graphical approaches (real-life examples, transformation activities, practical applications) could enhance student learning and engagement.

Addressing Resource Constraints: In the absence of ideal resources, teachers can be supported to make effective use of available materials. For example, simple strategies for creating accurate graphs without specialized equipment could be shared.

Managing Time Pressures: Strategies for integrating graphical work efficiently while maintaining quality could help teachers balance coverage demands with effective instruction.

4.10.3 Implications for Professional Development

The findings suggest that professional development opportunities focused on teaching coordinate geometry with graphical methods could address several identified needs:

- Training on using available resources effectively
- Exposure to a range of graphical methods and their applications
- Strategies for teaching coordinate geometry to students with weak foundations
- Approaches for managing graphical activities in large classes

- Introduction to technology-based methods and how to access or create resources

4.10.4 Implications for Policy and Resource Provision

The findings have implications for educational policy and resource provision:

Resource Allocation: The identified resource shortages suggest a need for increased allocation of teaching materials; particularly graph boards, graph paper, and potentially technology resources.

Curriculum Review: The time pressures teachers experience suggest a need to review curriculum pacing to allow adequate time for graphical work, which is essential for conceptual understanding.

Examination Alignment: The influence of examination demands on teaching practices suggests that ensuring alignment between assessment methods and effective pedagogical approaches could support improved instruction.

4.10.5 Limitations and Considerations

The findings should be interpreted with awareness of study limitations. The focus on three schools in one district means that findings may not be generalizable to all Zambian secondary schools. The self-report nature of some data (e.g., teacher questionnaire) may be subject to social desirability bias. The presence of the researcher during observations may have influenced teacher behavior (Hawthorne effect). Despite these limitations, the mixed-methods design and triangulation of data from multiple sources strengthen the credibility of findings.

4.11 Conclusion

This chapter has presented, analyzed, and interpreted data on teachers' use of graphical methods in teaching coordinate geometry in three secondary schools in Chongwe District. The findings reveal that while teachers use traditional manual graphical methods regularly, their repertoires are limited by resource constraints, time pressures, and training gaps. Students value graphical methods and perceive them as helpful for understanding, but experience challenges related to accuracy and insufficient practice.

The integration of findings across schools and with existing literature highlights both common patterns and contextual

variations. These findings provide a foundation for the conclusions and recommendations to be presented in Chapter Five.

V: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of the key findings from the study on teachers' use of graphical methods in teaching coordinate geometry in Chainda, Chalimbana, and Chongwe Secondary Schools in Chongwe District, Lusaka Province. The chapter synthesizes the evidence presented in Chapter Four and draws conclusions based on the research findings. It also offers recommendations for practice, policy, and further research. According to Shields, Schartner, and Curtis (2024), the final chapter of a research report should provide a cohesive synthesis of findings, clearly state the conclusions that can be drawn from the evidence, and offer actionable recommendations that are grounded in the research. The chapter is organized into six main sections: the introduction, a summary of the major findings organized by research question, conclusions derived from the findings, recommendations for various stakeholders, suggestions for further research, and a final conclusion that reflects on the significance of the study.

The study was guided by five research questions that focused on: (1) the graphical methods teachers use in teaching coordinate geometry, (2) the frequency with which these methods are employed, (3) the factors influencing teachers' selection and use of graphical methods, (4) the challenges teachers encounter when using graphical methods, and (5) how students respond to and engage with graphical methods. The findings addressed each of these questions through the collection and analysis of quantitative and qualitative data from 30 mathematics teachers and 150 students across the three schools, complemented by 15 classroom observations, 12 teacher interviews, and three student focus groups.

The significance of this chapter lies in its contribution to understanding mathematics instruction in Zambian secondary schools, particularly in the area of coordinate geometry—a foundational topic that underpins many advanced mathematical concepts. As Mashingaidze (2012) noted, the teaching of coordinate geometry and graphical methods has implications for students' overall mathematical development and their ability to engage with mathematics at higher levels. The

conclusions and recommendations presented here aim to contribute to improving mathematics education in Chongwe District and beyond.

5.2 Summary of Major Findings

This section presents a summary of the major findings organized according to three research questions that guided the study. The findings are synthesized from the data presented in Chapter Four, with attention to both the common patterns across schools and the variations that emerged.

5.2.1 Graphical Methods Used in Teaching Coordinate Geometry

The first research question sought to identify the graphical methods that mathematics teachers use in teaching coordinate geometry. The findings revealed that teachers employ a range of graphical methods, with traditional manual approaches being most prevalent. The methods used with greatest frequency include:

Plotting points on the Cartesian plane (mean frequency = 4.37): This foundational method was used by teachers across all three schools and was observed in 93.3% of lessons. Teachers reported that plotting points is an essential starting point for coordinate geometry instruction, as it establishes the basic conventions of the coordinate system.

Drawing graphs of linear equations (mean frequency = 4.23): This method was observed in 86.7% of lessons and was emphasized particularly for topics such as gradient and the equation of a straight line. Teachers noted that drawing graphs helps students visualize the relationship between algebraic equations and geometric representations.

Using the chalkboard or whiteboard to draw coordinate systems (mean frequency = 4.20): This method was used in all observed lessons (100%), reflecting its centrality in Zambian mathematics classrooms. The board serves as the primary medium for demonstration and whole-class instruction.

Employing graph boards and grids (mean frequency = 3.90): Graph boards were used in 60% of observed lessons, with significant variation across schools. Chongwe Secondary School, which had better access to these resources, reported higher frequency of use compared to Chainda and Chalimbana. Using real-life examples (mean frequency = 3.53) and incorporating visual aids (mean frequency = 3.47) were used occasionally, with teachers noting that these methods help

connect coordinate geometry to students' experiences and enhance engagement.

Transformation geometry activities (mean frequency = 3.33) and practical problem-solving (mean frequency = 3.27) were used less frequently, with considerable variation among teachers. These methods were more common in lessons with smaller class sizes or where teachers had received specialized training.

Technology-based methods such as graphing calculators (mean frequency = 1.83) and computer software (mean frequency = 1.67) were rarely used. Only one observed lesson (6.7%)

incorporated technology, and teachers across all three schools cited lack of equipment and training as barriers to technology use.

The findings revealed significant variation across schools in the use of graph boards and grids ($p = 0.046$), with Chongwe Secondary School reporting higher usage than Chainda and Chalmibana. This variation was attributed to differences in resource availability, as Chongwe had a larger supply of graph boards and more consistent access to graph paper.

5.2.2 Frequency of Graphical Methods in Coordinate Geometry Instruction

The second research question examined how frequently different graphical methods are employed in coordinate geometry instruction. The findings revealed that frequency patterns vary by method, topic, grade level, and school context. Overall frequency: Fifty percent of teachers reported using graphical methods "often" or "always" in their coordinate geometry instruction, while 33.3% used them "sometimes," and 16.6% used them "rarely" or "never." This indicates that while graphical methods are a regular part of instruction for many teachers, they are not universally or consistently employed.

Frequency by topic: Graphical methods were used most frequently for foundational topics such as plotting points (mean = 4.50), equations of straight lines (mean = 4.27), and gradient (mean = 4.13). For more advanced topics such as transformations (mean = 3.33), coordinate geometry applications (mean = 3.20), and circles and other curves (mean = 2.83), graphical methods were used less frequently. Teachers explained that these advanced topics are often taught through

algebraic approaches due to time constraints and the perceived difficulty of drawing complex graphs accurately.

Frequency by grade level: The use of graphical methods decreased as students progressed through the secondary grades, with highest frequency in Grade 10 (mean = 4.17), followed by Grade 11 (mean = 3.93), and Grade 12 (mean = 3.67). This pattern reflects the curriculum structure, where coordinate geometry is introduced in Grade 10 with an emphasis on graphical work, while higher grades focus more on applications and problem-solving. However, some teachers expressed concern that reducing graphical work in higher grades may disadvantage students who still struggle with foundational graphical concepts.

Technology frequency: Technology-based graphical methods were used rarely across all schools and teacher experience levels. Early-career teachers (0-5 years' experience) reported slightly higher use (mean = 2.13) compared to experienced teachers (16+ years, mean = 1.25), suggesting that newer teachers may have greater familiarity with technology from their

training. However, even among early-career teachers, the frequency remained low due to lack of access to equipment.

5.2.3 Factors Influencing Teachers' Selection and Use of Graphical Methods

The third research question explored the factors that influence teachers' selection and use of graphical methods. The findings revealed a complex interplay of curriculum, student, resource, time, and personal factors.

Curriculum requirements and syllabus guidance (mean influence = 4.53) emerged as the most influential factor. Teachers reported that the Zambian mathematics syllabus provides clear guidance on the graphical skills students must develop, and they align their instruction accordingly. However, some teachers noted that the syllabus focuses on content rather than pedagogical approaches, leaving them uncertain about the most effective methods to use.

Student background and prior knowledge (mean influence = 4.40) was the second most influential factor. Teachers adapt their use of graphical methods based on students' existing knowledge and learning needs. Students with weak foundational knowledge require more intensive graphical

support, while stronger students can engage with more advanced graphical concepts.

Assessment demands and examination preparation (mean influence = 4.33) significantly shaped teachers' method selection. Teachers prioritize graphical methods that align with examination requirements, focusing on skills that students will be tested on. This finding highlights the powerful influence of high-stakes assessments on instructional practices.

Availability of resources and teaching materials (mean influence = 4.07) was identified as a very influential factor. Teachers with better access to graph boards, graph paper, and other materials reported using graphical methods more frequently and with greater confidence. Resource shortages, particularly in Chainta and Chalmbar, constrained teachers' ability to implement graphical instruction effectively.

Time constraints and lesson pacing (mean influence = 3.87) created significant pressures. Teachers described the tension between spending adequate time on graphical work and covering the full curriculum within the allocated time. This often led to reduced or rushed graphical instruction, particularly for topics perceived as less likely to appear on examinations. Personal beliefs about mathematics teaching (mean influence = 3.70) and teacher training and professional development (mean influence = 3.47) also influenced method selection, though to a lesser extent. Teachers with constructivist beliefs and those who had received specific

training in teaching coordinate geometry reported using more varied and innovative graphical approaches.

Class size and classroom conditions (mean influence = 3.53) presented challenges, particularly for managing hands-on graphical activities and providing individual attention. Teachers with large classes (often exceeding 50 students) found it difficult to ensure that all students could see demonstrations and receive feedback on their graphical work.

5.2.4 Challenges Teachers Encounter When Using Graphical Methods

The fourth research question examined the challenges teachers face when using graphical methods to teach coordinate geometry. The findings revealed that teachers encounter multiple, interconnected challenges.

Resource shortages (mean challenge = 4.27) were the most severe challenge identified. Teachers across all three schools reported insufficient graph boards, graph paper, and technology resources. In Chainta Secondary School, teachers reported having only three graph boards for eight teachers, requiring sharing and sometimes teaching without these resources. The shortage of graph paper meant that students often had to draw graphs on notebook paper, leading to accuracy issues. The absence of technology resources (graphing calculators, computers, and projectors) prevented teachers from using dynamic graphical representations that could enhance student understanding.

Time constraints (mean challenge = 4.03) were identified as a major challenge. Teachers described the pressure to cover the extensive curriculum within limited time, which often led to reduced graphical work or rushed instruction. The mechanical aspects of drawing graphs take considerable time, particularly when students are learning, and teachers sometimes skipped detailed graphical work to keep pace with the syllabus.

Large class sizes (mean challenge = 3.90) presented significant challenges for graphical instruction. Teachers found it difficult to provide individual attention to students during graphical activities, ensure that all students could see demonstrations, and manage classroom behavior during hands-on work. With classes often exceeding 50 students, the quality of graphical instruction was compromised.

Students' weak mathematical foundation (mean challenge = 3.83) was identified as a major challenge. Teachers reported that many students lack prerequisite knowledge such as working with negative numbers, making it difficult to teach coordinate geometry effectively. Language barriers also presented challenges, as some students struggled with mathematical terminology in English, the medium of instruction.

Lack of appropriate technology (mean challenge = 3.80) was a significant barrier. While teachers recognized the potential value of technology-based graphical methods, the absence of equipment prevented implementation. Even teachers who had received training in technology use were unable to apply it due to resource constraints.

Inadequate teacher training (mean challenge = 3.53) was identified as a moderate to major challenge. Several teachers

felt that their pre-service training did not adequately prepare them to teach coordinate geometry with graphical methods, particularly in the resource-constrained contexts of Zambian schools. Limited in-service professional development opportunities meant that teachers had few opportunities to learn new approaches or share effective practices with colleagues.

5.2.5 Student Responses and Engagement with Graphical Methods

The fifth research question explored how students respond to and engage with graphical methods in coordinate geometry lessons. The findings revealed that students generally hold positive perceptions of graphical methods and value these approaches for learning.

Positive perceptions: Students agreed that graphical methods help them understand coordinate geometry better (mean = 4.13) and that they enjoy lessons where teachers use graphs and diagrams (mean = 4.07). Students also agreed that drawing graphs makes coordinate geometry more interesting (mean = 3.97) and helps them see real-life applications (mean = 3.87). **Understanding of concepts:** Students reported that graphical methods help them understand the reasoning behind formulas, supporting conceptual understanding rather than mere memorization. A Grade 11 student at Chongwe explained, "I used to just memorize the distance formula. But when the teacher showed us how it comes from the graph the right triangle I understood why the formula works."

Engagement: Students reported being more engaged when they actively participated in graphical activities rather than just watching demonstrations. A student at Chainda noted, "When the teacher gives us graph paper and we plot points ourselves, I pay more attention. When I'm drawing, I'm involved."

Challenges with accuracy: Students identified challenges with drawing graphs accurately, particularly when resources were inadequate. Without proper graph paper or rulers, students struggled to produce accurate graphs, leading to frustration and errors.

Desire for practice: Students expressed desire for more opportunities to practice graphical methods and receive individualized feedback. A student at Chainda noted, "I wish we had more time to practice so I can get better at drawing accurately."

No gender differences: Analysis of student perceptions by gender revealed no statistically significant differences,

indicating that graphical methods are equally accessible and appealing to male and female students.

Variations by grade level: While not statistically significant, there were trends suggesting that positive perceptions of graphical methods are strongest in Grade 10 and decrease somewhat in higher grades. This pattern aligns with the decreasing frequency of graphical instruction in higher grades.

5.2.6 Cross-School Comparisons

The findings revealed both common patterns across schools and variations based on contextual factors.

Common patterns across all three schools included:

- Dominance of traditional manual methods in graphical instruction Rare use of technology-based methods
- Resource constraints affecting quality and frequency of instruction Time pressures from curriculum coverage demands
- Positive student perceptions of graphical methods Variations included:
- Chongwe Secondary School had better access to graph boards and graph paper, corresponding to more frequent use of these resources
- Chongwe reported somewhat higher use of real-life examples and practical applications One teacher at Chongwe had received technology training, enabling limited use of graphing calculators

Chainda and Chalimbana faced more acute resource shortages

These variations suggest that resource availability and professional development opportunities can influence teachers' use of graphical methods, even within the same district.

5.3 Conclusions

Based on the summary of findings presented above, the following conclusions are drawn. These conclusions are grounded in the evidence collected and analyzed in this study, and they address the research questions that guided the investigation.

5.3.1 Conclusion 1: Traditional Manual Graphical Methods Dominate Instruction

The first conclusion is that traditional manual graphical methods—particularly plotting points, drawing graphs, and using the chalkboard—dominate instruction in coordinate geometry across the three schools. These methods are used consistently and frequently, reflecting their perceived

importance for developing foundational graphical skills. However, the dominance of these methods also indicates that teachers' instructional repertoires may be limited, with less frequent use of real-life examples, transformation activities, and practical applications that could enhance student engagement and conceptual understanding.

This conclusion aligns with the observation by Mashingaidze (2012) that teachers in resource-constrained contexts tend to rely on instructional approaches that require minimal equipment and preparation. While these traditional methods have value, their dominance may limit students' exposure to the full range of graphical representations and applications that are important for comprehensive understanding of coordinate geometry.

5.3.2 Conclusion 2: Technology-Based Graphical Methods Are Rarely Used

The second conclusion is that technology-based graphical methods such as graphing calculators and computer software are rarely used in coordinate geometry instruction across the three schools. This conclusion is supported by both teacher-reported data and classroom observations, which showed minimal technology use despite teachers' recognition of its potential value. The absence of technology is attributed to resource shortages (lack of equipment) and training gaps (teachers' limited familiarity with available technologies).

This finding is significant because research has demonstrated the potential of dynamic geometry software to enhance students' understanding of coordinate geometry concepts (Joswick, Williams, & Felton-Koestler, 2026). The lack of technology integration in these schools represents a missed opportunity for enriching graphical instruction and preparing students for technology-rich learning environments.

5.3.3 Conclusion 3: Curriculum and Assessment Demands Shape Instructional Practices

The third conclusion is that curriculum requirements and assessment demands are the most powerful influences on teachers' use of graphical methods. Teachers align their instruction with the syllabus guidance and focus on graphical skills that appear on examinations. This conclusion reflects the high-stakes nature of examinations in the Zambian education system, where student performance on national exams has significant implications for progression and opportunities.

While this alignment ensures that teachers address the required content, it may also constrain innovation and limit the use of graphical methods that are educationally valuable but not directly assessed. As noted by Shields et al. (2024), when assessment drives instruction, teachers may prioritize test preparation over broader educational goals.

5.3.4 Conclusion 4: Resource Constraints Significantly Impede Quality Instruction

The fourth conclusion is that resource constraints—particularly shortages of graph boards, graph paper, and technology—significantly impede the quality and frequency of graphical instruction across all three schools. Teachers consistently identified resource shortages as the most severe challenge, and variations in resource availability explained differences in practice between schools.

This conclusion has important implications for educational equity. Students in schools with better resources (such as Chongwe Secondary School) may receive more frequent and higher-quality graphical instruction than students in schools with fewer resources. This disparity may contribute to differences in mathematics achievement and preparation for higher-level mathematics.

5.3.5 Conclusion 5: Time Pressures Reduce Opportunities for Graphical Work

The fifth conclusion is that time pressures created by curriculum coverage demands lead to reduced or rushed graphical instruction. Teachers described the tension between spending adequate time on graphical work and covering the full syllabus within the allocated time. This often resulted in prioritizing algebraic approaches over graphical approaches, particularly for topics perceived as time-consuming.

This conclusion is concerning because adequate time for graphical work is essential for developing proficiency in coordinate geometry. As Mashingaidze (2012) noted, students need sustained practice with graphical representations to develop both procedural skills and conceptual understanding.

5.3.6 Conclusion 6: Students Value Graphical Methods and Perceive Them as Helpful

The sixth conclusion is that students generally hold positive perceptions of graphical methods and value these approaches for learning coordinate geometry. Students report that graphical methods help them understand concepts, make learning more

interesting, and help them see real-life applications. Students also express appreciation for active participation in graphical activities and desire more opportunities for practice and feedback.

This conclusion is encouraging, as it suggests that students are receptive to graphical instruction and recognize its benefits. The positive student responses provide a strong rationale for enhancing and expanding graphical instruction in mathematics classrooms. The absence of gender differences in student perceptions also indicates that graphical methods are accessible and appealing to all students.

5.3.7 Conclusion 7: Teacher Training Gaps Limit Instructional Repertoires

The seventh conclusion is that gaps in teacher training and professional development limit teachers' instructional repertoires and their ability to implement varied graphical methods effectively. Teachers reported that their pre-service training did not adequately prepare them for teaching coordinate geometry with graphical methods in resource-constrained contexts. Limited in-service professional development opportunities meant that teachers had few opportunities to learn new approaches or share effective practices.

This conclusion suggests that investing in teacher training and professional development could yield significant returns in terms of improving the quality of graphical instruction. Teachers who have received specialized training report greater confidence and variety in their approaches, as evidenced by the teacher at Chongwe who used graphing calculators after attending a workshop.

5.3.8 Conclusion 8: Large Class Sizes Complicate Graphical Instruction

The eighth conclusion is that large class sizes present significant challenges for graphical instruction, affecting teachers' ability to provide individual attention, ensure visibility of demonstrations, and manage hands-on activities. With classes often exceeding 50 students, the quality of graphical instruction is compromised.

This conclusion reflects the broader challenge of overcrowded classrooms in Zambian secondary schools (Ministry of Education, 2023). While class size is not a factor that individual teachers can control, its impact on instruction must be acknowledged in efforts to improve mathematics education.

5.3.9 Conclusion 9: Students' Weak Foundational Knowledge Creates Barriers

The ninth conclusion is that students' weak foundational knowledge in mathematics creates significant barriers to effective instruction in coordinate geometry. Teachers reported that many students lack prerequisite skills such as working with negative numbers,

understanding fractions, and interpreting basic graphs. These gaps require teachers to spend time on foundational concepts, reducing time available for coordinate geometry instruction.

This conclusion highlights the cumulative nature of mathematics learning. Students who fall behind in earlier grades struggle to catch up when they encounter coordinate geometry. Addressing foundational gaps requires coordinated efforts across grade levels and attention to the progression of mathematical skills.

5.3.10 Conclusion 10: Contextual Factors Shape Practice across Schools

The tenth conclusion is that contextual factors—including resource availability, school history, and professional development opportunities—shape teachers' use of graphical methods across schools. While there were many common patterns across the three schools, variations existed that corresponded to differences in resources and opportunities.

This conclusion affirms the importance of context in understanding educational practice. As Coe et al. (2025) note, educational research must attend to the specific conditions in which teaching and learning occur. Efforts to improve graphical instruction must consider the unique contexts of each school and develop strategies that are appropriate for those contexts.

5.4 Recommendations

Based on the findings and conclusions of this study, the following recommendations are offered for various stakeholders. The recommendations are organized by target audience: the Ministry of Education, school administrators, mathematics teachers, teacher education institutions, and further research.

5.4.1 Recommendations for the Ministry of Education Recommendation 1: Enhance Resource Provision for Graphical Instruction

The Ministry of Education should prioritize the provision of resources that support graphical instruction in secondary

schools. This includes ensuring that every mathematics department has an adequate supply of graph boards, graph paper, rulers, and other materials necessary for effective graphical work. Given the variations in resource availability identified in this study, particular attention should be paid to schools in peri-urban and rural areas that may have fewer resources.

Rationale: Resource shortages were identified as the most severe challenge affecting graphical instruction. Improving resource provision would directly address this

challenge and enable teachers to implement graphical methods more effectively. This recommendation is consistent with the findings of the Chongwe Municipal Council (2025) regarding the need for improved educational infrastructure and resources. Recommendation 2: Invest in Technology Infrastructure and

Training

The Ministry should develop a comprehensive strategy for integrating technology into mathematics instruction, including the provision of graphing calculators, computers, and software such as GeoGebra. This strategy should include not only equipment provision but also sustained professional development to ensure that teachers can use technology effectively. A phased approach, beginning with pilot schools and scaling up based on lessons learned, would be appropriate. Rationale: Technology-based graphical methods were rarely used in the three schools despite their potential to enhance learning. Investment in technology would enable teachers to use dynamic representations that can improve student understanding of coordinate geometry concepts (Joswick et al., 2026).

Recommendation 3: Review Curriculum Pacing to Allow Adequate Time for Graphical

Work

The Ministry should review the mathematics curriculum to ensure that adequate time is allocated for graphical work in coordinate geometry. This may involve reducing the number of topics covered or extending the time allocated for coordinate geometry instruction. Curriculum review should also consider the progression of graphical skills across grade levels to ensure that students receive consistent and cumulative instruction.

Rationale: Time pressures were identified as a major challenge that led to reduced or rushed graphical instruction. Adjusting curriculum pacing would allow teachers to spend adequate time on graphical work without sacrificing coverage of other essential topics.

Recommendation 4: Align Assessment with Effective Pedagogical Approaches

The Ministry should review assessment practices to ensure that they support, rather than constrain, effective pedagogical approaches. While examinations appropriately assess graphical skills, they should not discourage teachers from using innovative graphical methods that may be educationally valuable but not directly assessed. Consideration should be given to including items that assess conceptual understanding developed through varied graphical approaches.

Rationale: Assessment demands were identified as a powerful influence on instructional practices. Ensuring alignment between assessment and effective pedagogy would encourage teachers to use a wider range of graphical methods.

5.4.2 Recommendations for School Administrators

Recommendation 5: Strengthen Resource Management and Allocation

School administrators, particularly head teachers and heads of mathematics departments, should strengthen the management and allocation of resources for graphical instruction. This includes maintaining an inventory of graph boards, ensuring that graph paper is available for students, and establishing systems for sharing resources fairly among teachers. Where resources are limited, administrators should explore creative solutions such as creating low-cost graph boards or partnering with community organizations to obtain materials.

Rationale: Resource availability varied across schools, with those having better resources reporting more frequent and effective graphical instruction. Strengthening resource management can help ensure that available resources are used optimally.

Recommendation 6: Provide School-Based Professional Development

School administrators should organize and support school-based professional development focused on teaching coordinate geometry with graphical methods. This could include peer observation, lesson study groups, and sharing of effective practices among mathematics teachers. Administrators should also facilitate teachers' participation in

district-level and national professional development opportunities.

Rationale: Teachers reported limited opportunities for professional development focused on mathematics instruction. School-based professional development can address this gap and provide ongoing support for improving instructional practice.

Recommendation 7: Address Class Size Challenges through Creative Strategies

While class size is often beyond the control of individual schools, administrators can implement strategies to mitigate its impact on graphical instruction. This may include providing teaching assistants for large classes, organizing students into smaller groups for hands-on activities, and ensuring that classrooms have adequate space and visibility for graphical demonstrations. Administrators should also advocate for reduced class sizes where possible. Rationale: Large class sizes were identified as a major challenge affecting graphical instruction. Creative strategies can help mitigate these challenges while awaiting longer-term solutions.

5.4.3 Recommendations for Mathematics Teachers

Recommendation 8: Expand Repertoire of Graphical Methods
Mathematics teachers should actively seek to expand their repertoire of graphical methods beyond traditional approaches. This includes incorporating real-life examples, transformation activities, practical problem-solving, and, where possible, technology-based methods. Teachers can collaborate with colleagues to share effective approaches and learn from each other's experiences.

Rationale: The study found that teachers primarily used traditional manual methods, with less frequent use of other graphical approaches. Expanding instructional repertoires can enhance student engagement and learning.

Recommendation 9: Develop Strategies for Efficient Graphical Instruction

Teachers should develop and share strategies for conducting graphical instruction efficiently within time constraints. This may include techniques for quickly drawing accurate graphs, using student helpers to prepare materials, and integrating graphical work with other topics to maximize time use. Teachers can also develop systems for providing feedback on student graphs without consuming excessive class time.

Rationale: Time pressures were identified as a significant challenge. Developing efficient strategies can help teachers maintain quality graphical instruction while meeting curriculum coverage requirements.

Recommendation 10: Support Students with Weak Foundations

Teachers should identify and support students with weak mathematical foundations, particularly those who struggle with prerequisite skills for coordinate geometry. This may involve providing additional practice, using targeted interventions, and differentiating instruction to meet diverse student needs. Teachers can also collaborate with colleagues in lower grades to strengthen the mathematics foundation across grade levels.

Rationale: Students' weak foundational knowledge was identified as a major challenge affecting coordinate geometry instruction. Proactive support can help address these gaps and improve student outcomes.

Recommendation 11: Create Opportunities for Student Practice and Feedback Teachers should provide regular opportunities for students to practice graphical

methods and receive individualized feedback. This may include using class time for hands-on graphical activities, collecting and reviewing student graphs, and providing specific feedback on accuracy and understanding. Teachers can also incorporate peer feedback and self-assessment to increase the frequency of feedback.

Rationale: Students expressed desire for more practice and feedback. Creating these opportunities can improve student proficiency and confidence with graphical methods.

5.4.4 Recommendations for Teacher Education Institutions

Recommendation 12: Strengthen Pre-Service Training on Teaching Coordinate Geometry

Teacher education institutions should strengthen pre-service training on teaching coordinate geometry with graphical methods. This training should include not only theoretical understanding of coordinate geometry but also practical strategies for teaching graphical methods in resource-constrained contexts. Prospective teachers should have opportunities to practice teaching coordinate geometry and receive feedback on their instruction.

Rationale: Teachers reported that their pre-service training did not adequately prepare them for teaching coordinate geometry effectively. Strengthening training would better prepare new teachers for the realities of Zambian secondary schools.

Recommendation 13: Integrate Technology Training into Mathematics Education Programs

Teacher education institutions should integrate technology training into mathematics education programs, ensuring that prospective teachers are familiar with graphing calculators, dynamic geometry software, and other technologies that support graphical instruction. Training should focus not only on technical skills but also on pedagogical strategies for integrating technology effectively.

Rationale: The limited use of technology in schools reflects both resource constraints and training gaps. Preparing teachers to use technology would enable them to integrate it when resources become available.

5.4.5 Recommendations for Further Research

Recommendation 14: Conduct Large-Scale Studies on Graphical Instruction

Further research should be conducted on teachers' use of graphical methods in teaching coordinate geometry across a larger and more diverse sample of Zambian secondary schools. This would enable generalization of findings and identification of patterns that may vary by region, school type, and other factors. Large-scale studies could also examine the relationship between teachers' use of graphical methods and student learning outcomes.

Rationale: This study focused on three schools in one district. Larger-scale studies would provide a more comprehensive picture of graphical instruction in Zambian secondary schools. Recommendation 15: Investigate the Impact of Professional Development on Practice Research should investigate the impact of different professional development approaches on teachers' use of graphical methods. This could include experimental or quasi-experimental studies comparing the effectiveness of various professional development models, as well as qualitative studies exploring how teachers integrate new learning into their practice. Rationale: Teachers identified limited professional development as a challenge.

Research on effective professional development would inform efforts to support teachers.

Recommendation 16: Examine Student Learning Outcomes Related to Graphical Instruction

Further research should examine the relationship between teachers' use of graphical methods and student learning outcomes in coordinate geometry. This could include studies that assess student understanding, identify which graphical methods are most effective for different types of learning, and explore how student characteristics influence the effectiveness of different approaches.

Rationale: While this study explored student perceptions of graphical methods, it did not assess learning outcomes directly. Research on learning outcomes would provide evidence for the effectiveness of different instructional approaches.

Recommendation 17: Explore Technology Integration Strategies for Resource-Constrained Contexts

Research should explore innovative strategies for integrating technology into graphical instruction in resource-constrained contexts. This could include studies of low-cost technologies, mobile-based learning, and strategies for maximizing the impact of limited technology resources

Rationale: The absence of technology in the three schools reflects broader resource constraints. Research on feasible technology integration strategies would provide practical guidance for schools with limited resources.

Recommendation 18: Investigate Strategies for Addressing Foundational Gaps Further research should investigate effective strategies for addressing students' weak foundational knowledge in mathematics. This could include studies of remedial interventions, cross-grade collaboration, and curriculum articulation strategies that help ensure students develop prerequisite skills before encountering coordinate geometry.

Rationale: Students' weak foundational knowledge was identified as a significant barrier to effective coordinate geometry instruction. Research on addressing this issue would have broad implications for mathematics education.

5.5 Contributions of the Study

This study makes several contributions to knowledge about mathematics education in Zambian secondary schools.

5.5.1 Empirical Contributions

The study provides empirical evidence on teachers' use of graphical methods in teaching coordinate geometry in a specific context—Chongwe District. This evidence addresses a gap in the literature, as limited research has been conducted on mathematics instruction in Zambian secondary schools, particularly in the area of coordinate geometry. The mixed-methods design and triangulation of data from multiple sources strengthen the credibility of the findings.

5.5.2 Practical Contributions

The study offers practical insights for teachers, school administrators, and policymakers seeking to improve graphical instruction. The identification of specific challenges—resource shortages, time pressures, large class sizes, training gaps—provides a basis for targeted interventions. The recommendations offered in this chapter are grounded in the findings and address the real-world constraints that teachers face.

5.5.3 Methodological Contributions

The study demonstrates the value of mixed-methods research for understanding complex educational phenomena. By combining quantitative data on the frequency and patterns of graphical instruction with qualitative data on teachers' experiences and students' perspectives, the study provides a comprehensive picture that would not be possible with a single method. The multiple-case design also demonstrates how contextual factors shape practice within the same district.

5.6 Limitations of the Study

The findings and conclusions of this study should be interpreted in light of its limitations.

Limited Generalizability: The study focused on three schools in one district, and the findings may not be generalizable to all Zambian secondary schools. The purposive selection of schools, while appropriate for case study research, limits the extent to which findings can be generalized to other contexts.

Self-Report Data: Some data were collected through self-report instruments (teacher questionnaires), which may be subject to social desirability bias. Teachers may have reported more frequent or varied use of graphical methods than actually occurred. The use of classroom observations helped mitigate this limitation by providing direct evidence of practice.

Observer Effects: The presence of the researcher during classroom observations may have influenced teacher behavior (Hawthorne effect). Teachers may have used graphical methods more frequently or in different ways than they would have under normal conditions. Efforts to minimize this effect included spending time in schools before observations and conducting multiple observations to allow teachers to become accustomed to the observer's presence.

Cross-Sectional Design: The study employed a cross-sectional design, collecting data at a single point in time. This design cannot capture changes in practice over time or establish causal relationships between variables.

Limited Student Outcome Data: While the study explored student perceptions of graphical methods, it did not include direct assessment of student learning outcomes. Therefore, conclusions about the effectiveness of different graphical methods for promoting learning are based on teacher and student reports rather than direct evidence.

5.7 Conclusion

This study investigated teachers' use of graphical methods in teaching coordinate geometry in three secondary schools in Chongwe District, Lusaka Province. The findings reveal that while teachers use traditional manual graphical methods regularly, their instructional repertoires are constrained by resource shortages, time pressures, large class sizes, and training gaps. Students value graphical methods and perceive them as helpful for understanding, but they experience challenges related to accuracy and insufficient practice.

The conclusions drawn from this study highlight the importance of addressing systemic challenges to improve graphical instruction. Resource provision, curriculum pacing, teacher training, and class size reduction all emerged as areas requiring attention. At the same time, the positive student responses to graphical methods provide encouragement that investments in this area can yield meaningful returns.

The recommendations offered in this chapter provide a roadmap for stakeholders seeking to enhance graphical instruction in Zambian secondary schools. Implementation of these recommendations will require coordinated effort at multiple levels—from national policy to school leadership to classroom practice. However, the potential benefits—improved student understanding of coordinate geometry, enhanced engagement with mathematics, and better preparation for

higher-level mathematical learning—make this effort worthwhile.

As noted by Shields et al. (2024), educational research has value when it contributes to improving practice and informing policy. This study aims to fulfill that purpose by providing evidence that can guide efforts to strengthen mathematics instruction in Zambian secondary schools. The challenge of teaching coordinate geometry through graphical methods is not unique to Zambia, but the specific conditions of Zambian schools—resource constraints, large classes, diverse student backgrounds—require contextually appropriate solutions. It is the hope of the researcher that the findings, conclusions, and recommendations presented here will contribute to developing those solutions.

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