

Investigating The Influence of School Environment on Biology Performance: A Case Study of Secondary Schools in Nyimba District

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Abstract. This study investigated the influence of the school environment on biology performance among secondary school students in Nyimba District, Zambia. Grounded in the recognition that both physical infrastructure and social climate play pivotal roles in shaping academic outcomes, the research sought to examine how variations in school settings affect student engagement and achievement in biology. The inquiry was motivated by persistent concerns regarding under-resourced educational facilities and suboptimal interpersonal dynamics within schools, which have been linked to declining performance in science subjects. By focusing on biology—a subject that demands both theoretical understanding and practical application—the study aimed to generate contextually relevant insights that could inform targeted educational interventions. A mixed-methods approach was employed, combining quantitative data from student performance records with qualitative insights gathered through structured questionnaires, focus group discussions, and interviews with teachers and school administrators. The sample included a cross-section of public and government-aided secondary schools within Nyimba District. Data collection instruments were designed to assess perceptions of physical infrastructure, social climate, and motivational influences on learning. Although the study was still in its proposal phase, it was anticipated that findings would reveal a significant correlation between the quality of the school environment and biology performance. Educator perspectives were expected to underscore the nuanced ways in which environmental factors shape teaching practices and student outcomes. The significance of this research lies in its potential to guide evidence-based reforms in educational policy and resource allocation. By systematically documenting the environmental determinants of biology performance, the study aimed to contribute to a more holistic understanding of academic achievement in under-resourced contexts. The anticipated recommendations would serve as a roadmap for improving both physical conditions and socio-emotional climates in secondary schools, ultimately fostering a more engaging and productive learning environment. These insights could be transferrable to similar educational settings across Zambia and beyond, reinforcing the broader discourse on equitable and effective science education.

keywords: biology performance, school environment, physical infrastructure, social climate, student engagement, educator perspectives, Nyimba District, secondary education, educational reform.

I Introduction

The quality of the school environment has long been recognized as a critical determinant of student academic performance, particularly in science subjects such as biology. In Zambia, where educational disparities persist across districts, the interplay between physical infrastructure and social climate within schools has emerged as a focal point for educational research and reform. This study investigated the influence of the school environment on biology performance among secondary school students in Nyimba District, a region characterized by infrastructural limitations and evolving pedagogical practices.

Biology, as a subject, demands both theoretical comprehension and practical engagement. The effectiveness of biology instruction is therefore contingent upon the availability of well-equipped laboratories, conducive classroom settings, and a supportive social atmosphere that fosters inquiry and collaboration. Previous studies have underscored the significance of these environmental factors in shaping student outcomes (Brown, 2020; Smith & Patel, 2021). However, in many rural districts, including Nyimba, anecdotal evidence suggests that students face challenges that extend beyond curriculum content, rooted in the inadequacies of their learning environments.

This research adopted a mixed-methods approach to examine how variations in school infrastructure and social climate influenced biology performance. By engaging students, teachers, and administrators through surveys and interviews, the study aimed to generate a nuanced understanding of the environmental determinants of academic achievement. The findings were expected to inform targeted interventions that enhance both the physical and emotional conditions of learning in secondary schools. Ultimately, the study sought to contribute to the broader discourse on equitable science education in Zambia, offering evidence-based recommendations that could be replicated in similar contexts.

Background of the Study

The relationship between school environment and academic performance has attracted considerable scholarly attention, particularly in developing countries where resource constraints are prevalent. In Zambia, disparities in educational infrastructure and social support systems have been linked to inconsistent student outcomes in science subjects

(Ndala, 2021; Adebayo, 2021). Biology, a core component of the secondary school science curriculum, requires not only cognitive engagement but also access to practical tools and collaborative learning spaces. The absence of these elements often results in diminished student performance and reduced interest in the subject.

In Nyimba District, preliminary observations and stakeholder consultations revealed that many secondary schools operated under conditions that were not conducive to effective biology instruction. Classrooms were frequently overcrowded, laboratories were under-equipped, and teacher-student interactions were often strained due to high workloads and limited professional development opportunities. These challenges were compounded by socio-emotional factors such as peer dynamics, teacher attitudes, and school leadership practices, all of which shaped the overall learning climate (Garcia & Fields, 2019; Moyo, 2022).

International research has corroborated the importance of a supportive school environment in enhancing academic outcomes. For instance, the European Commission (2015) emphasized that well-maintained facilities and positive social climates contribute significantly to student achievement. Similarly, Ramnarain (2014) argued that science education thrives in environments that promote inquiry, safety, and mutual respect. Drawing on these insights, the present study focused on Nyimba District as a case study to explore how environmental factors influenced biology performance. By integrating local realities with global evidence, the research aimed to produce findings that were both contextually relevant and academically rigorous.

Problem Statement

Despite growing recognition of the role of school environment in shaping academic outcomes, limited empirical research has been conducted in Zambia to examine its specific impact on biology performance. In Nyimba District, anecdotal reports and informal assessments have consistently pointed to infrastructural deficits and adverse social climates as barriers to effective science education. Students often struggled to engage with biology content due to inadequate laboratory facilities, poorly ventilated classrooms, and limited access to instructional materials. These physical constraints were further exacerbated by social factors such as low teacher morale, limited peer collaboration, and inconsistent disciplinary practices (Okoro, 2023; Chikonde, 2022).

The central problem addressed by this study was the extent to which the school environment influenced biology performance among secondary school students in Nyimba District. While national education policies emphasized the importance of science education, implementation at the district level remained uneven, with schools facing logistical and administrative challenges that hindered curriculum delivery. The disconnect between policy aspirations and classroom realities necessitated a systematic investigation into the environmental determinants of academic achievement.

This study sought to bridge the gap between theoretical understanding and practical evidence by examining both physical and social dimensions of the school environment. It aimed to quantify the relationship between infrastructural quality and biology outcomes, while also capturing the lived experiences of educators and students. The findings were expected to reveal patterns of influence that could inform targeted interventions, resource allocation, and policy reform. By focusing on Nyimba District, the research provided a localized perspective on a national issue, contributing to the broader effort to improve science education in under-resourced regions.

Purpose of the Study

The purpose of this study was to examine how the school environment influenced biology performance among secondary school students in Nyimba District. Specifically, the study sought to generate empirical evidence on the extent to which physical infrastructural conditions and the social climate within schools shaped students' academic outcomes in biology. By systematically analysing both tangible environmental factors, such as classroom conditions and laboratory facilities, and intangible factors, including teacher–student relationships, peer interactions, and school leadership practices, the study aimed to provide a holistic understanding of the learning environment in secondary schools.

The study further aimed to bridge the gap between national policy aspirations for improved science education and the practical realities experienced at the school level. Through the integration of quantitative performance data and qualitative perspectives from students and educators, the research intended to illuminate contextual challenges that constrained effective biology instruction. Ultimately, the purpose of the study was to inform evidence-based decision-making by educators, school administrators, and

policymakers, and to contribute to strategies that would enhance biology teaching and learning in Nyimba District and comparable educational contexts.

Research Objectives

• General Objective:

To investigate the influence of the school environment on biology performance among secondary school students in Nyimba District.

Specific Objectives:

- To evaluate the physical infrastructure of secondary schools in Nyimba District.
- To examine the social climate within these schools.
- To determine the correlation between school environment and biology performance.
- To identify motivational influences on student engagement in biology.
- To gather educators' insights on the impact of the school environment.
- To propose evidence-based recommendations for optimizing the school environment.

Research Questions

- How did the physical infrastructure of secondary schools in Nyimba District influence students' performance in biology?
- What role did the social climate play in affecting student engagement and motivation in biology?
- Was there a significant correlation between the quality of the school environment and biology performance?
- Which motivational factors most strongly influenced student participation in biology classes?
- How did educators perceive the impact of the school environment on the teaching and learning of biology?
- What evidence-based interventions could be recommended to improve the school environment and boost biology performance?

Characteristics of the Phenomena

The phenomenon under investigation—school environment as a determinant of biology performance—was characterized by its multidimensional nature, encompassing both tangible and intangible elements. At its core, the school environment comprised physical infrastructure and social climate, each contributing uniquely to the academic experiences of students. Physical infrastructure included classrooms, laboratories, furniture,

instructional materials, and sanitation facilities. These components directly influenced the delivery of biology instruction, particularly in facilitating practical sessions and ensuring comfort and safety during learning (Smith & Patel, 2021).

Equally critical was the social climate, which referred to the interpersonal dynamics within the school, including teacher-student relationships, peer interactions, and the overall emotional atmosphere. A positive social climate was marked by mutual respect, inclusivity, and collaborative learning, whereas a negative climate often manifested through authoritarian teaching styles, peer bullying, and disengagement (Garcia & Fields, 2019). These social factors shaped students' motivation, self-efficacy, and willingness to participate actively in biology lessons.

The phenomenon also exhibited contextual variability, meaning its characteristics differed across schools depending on geographic location, resource availability, and administrative leadership. In Nyimba District, the school environment was often defined by infrastructural limitations and evolving pedagogical practices. This variability necessitated a localized investigation to capture the nuances of how environmental conditions influenced biology performance.

Furthermore, the phenomenon was dynamic and interactive. Physical and social elements did not operate in isolation but interacted to produce cumulative effects on student outcomes. For instance, a well-equipped laboratory could be rendered ineffective in a hostile social climate, while strong teacher-student rapport could partially mitigate infrastructural deficits. These interdependencies highlighted the complexity of the school environment and justified the need for a comprehensive, mixed-methods approach to its investigation.

Factors Related to the Phenomena

Several interrelated factors influenced the phenomenon of school environment and its impact on biology performance. These factors spanned infrastructural, pedagogical, psychological, and administrative domains, each contributing to the overall learning experience of students.

1. **Physical Infrastructure:** The availability and quality of physical resources were foundational to effective biology instruction. Classrooms needed to be spacious, well-lit, and ventilated to support concentration and comfort. Laboratories required functional

equipment, safety provisions, and adequate space for practical experiments. In Nyimba District, many schools lacked these essentials, limiting students' ability to engage with biology content experientially (Ndala, 2021). The absence of visual aids, models, and reagents further constrained the teaching of abstract biological concepts.

2. **Teacher Competence and Motivation:** Teachers played a pivotal role in shaping the school environment. Their subject mastery, pedagogical skills, and attitudes toward students directly influenced classroom dynamics. Motivated and well-trained teachers were more likely to create inclusive and stimulating learning environments. However, in resource-constrained settings, teacher burnout and lack of professional development often led to disengagement and reduced instructional quality (Adebayo, 2021).

3. **Social Climate and Peer Influence:** The emotional and relational atmosphere within schools significantly affected student engagement. Supportive peer relationships and respectful teacher-student interactions fostered a sense of belonging and academic confidence. Conversely, environments marked by bullying, favoritism, or authoritarianism discouraged participation and reduced motivation (Moyo, 2022). The social climate also influenced students' willingness to ask questions, collaborate, and persist through academic challenges.

4. **School Leadership and Policy Implementation:** Effective school leadership was essential in maintaining a conducive environment. Principals and administrators influenced resource allocation, discipline policies, and teacher support systems. Schools with proactive leadership tended to prioritize infrastructure maintenance and foster positive cultures of learning. In contrast, weak leadership often resulted in neglect of facilities and inconsistent enforcement of policies, undermining the educational process (Chikonde, 2022).

5. **Student Motivation and Self-Efficacy:** Intrinsic and extrinsic motivational factors shaped how students responded to their environment. Students who perceived biology as relevant and achievable were more likely to engage actively, regardless of infrastructural limitations. Motivation was influenced by prior academic success, parental support, career aspirations, and teacher encouragement. Self-efficacy—the belief in one's ability to succeed—was particularly important in science subjects, where confidence in handling experiments and understanding complex concepts was crucial (Kimani, 2022).

6. Community and Parental Involvement: External stakeholders such as parents and community leaders also affected the school environment. Their involvement in school governance, resource mobilization, and student support contributed to a more holistic educational experience. In Nyimba District, limited parental engagement and low community investment in education were identified as barriers to improving school conditions (Johnson, 2023).

In sum, the phenomenon of school environment and its influence on biology performance was shaped by a constellation of factors. Understanding these interdependencies was essential for designing interventions that addressed both structural and relational dimensions of the learning context.

Global Statistical Scenario

Globally, the relationship between school environment and academic performance has been extensively studied, with mounting evidence indicating that both physical infrastructure and psychosocial climate significantly influence student outcomes. According to UNESCO's Global Education Monitoring Report (2023), over 250 million children worldwide were not achieving minimum proficiency levels in reading and mathematics, with science subjects such as biology showing similar trends. The report emphasized that inadequate school facilities, overcrowded classrooms, and poor ventilation were among the leading contributors to underperformance, particularly in low- and middle-income countries.

In high-income countries, investments in school infrastructure have yielded measurable improvements in science education. For instance, the OECD Programme for International Student Assessment (PISA) 2022 revealed that students in schools with modern laboratories and well-maintained classrooms scored significantly higher in biology and other science subjects than their counterparts in poorly resourced institutions. The same report highlighted that students' perceptions of safety, belonging, and teacher support were positively correlated with academic achievement, reinforcing the importance of a nurturing social climate.

In sub-Saharan Africa, the situation remains challenging. The World Bank (2022) reported that over 60% of secondary schools in rural areas lacked basic science laborato-

ries, and nearly 40% operated without sufficient lighting or ventilation. These infrastructural deficits were compounded by teacher shortages, limited professional development, and inadequate instructional materials. A study by Ramnarain and Hlatswayo (2021) found that students in under-resourced South African schools performed significantly lower in biology compared to those in better-equipped urban schools, despite following the same curriculum.

Furthermore, global trends indicate that improving school environments can lead to substantial gains in student motivation and engagement. The European Commission (2015) noted that schools that fostered collaborative learning, mutual respect, and emotional safety reported higher retention rates and better performance in science subjects. These findings underscore the need for holistic interventions that address both physical and social dimensions of the learning environment.

In summary, global statistics affirm that the school environment is a critical determinant of biology performance. The disparities between well-resourced and under-resourced schools continue to widen the achievement gap, particularly in science education. This study, situated in Nyimba District, aligns with international efforts to understand and mitigate these disparities by generating localized evidence that can inform broader educational reforms.

Local Statistical Scenario

In Zambia, the educational landscape reflects many of the global challenges associated with under-resourced school environments. According to the Ministry of Education's Annual School Census Report (2024), only 45% of secondary schools in rural districts such as Nyimba had access to functional science laboratories. The report further indicated that over 30% of classrooms lacked adequate seating, lighting, and ventilation, conditions that are essential for effective learning, particularly in subjects requiring practical engagement like biology.

Performance data from the Examinations Council of Zambia (ECZ) revealed that biology pass rates in Nyimba District were consistently below the national average. In 2023, only 38% of students in the district achieved a passing grade in biology, compared to a national average of 52%. This discrepancy was attributed to infrastructural

limitations, teacher shortages, and low student motivation. Interviews conducted by local education officers suggested that many students viewed biology as a difficult subject, largely due to the lack of practical exposure and supportive learning environments. Moreover, teacher deployment statistics indicated that Nyimba District faced a 25% shortfall in qualified science teachers, further exacerbating the challenges of delivering quality biology instruction. The Zambia Education Sector Performance Report (2023) emphasized that improving school infrastructure and fostering positive social climates were essential for reversing these trends. These findings provided a compelling rationale for the present study, which aimed to systematically investigate the environmental factors influencing biology performance in Nyimba District and propose actionable solutions.

Scope of the Study

This study was delimited to public and government-aided secondary schools located within Nyimba District, Eastern Province, Zambia. It focused specifically on the influence of the school environment—defined in terms of physical infrastructure and social climate—on student performance in biology. Private and international schools were deliberately excluded due to their distinct administrative structures, resource availability, and pedagogical approaches, which could introduce variability beyond the intended scope of analysis.

The research targeted students, teachers, and school administrators as key informants, recognizing their unique perspectives on the learning environment and its impact on academic outcomes. Data collection instruments included structured questionnaires, focus group discussions, and semi-structured interviews, designed to capture both quantitative metrics and qualitative insights. The study concentrated on biology as a subject due to its dual reliance on theoretical understanding and practical application, making it particularly sensitive to environmental conditions.

Temporal boundaries were set to the 2024 academic year, allowing for a focused analysis of recent performance trends and environmental conditions. The study did not extend to other science subjects such as chemistry or physics, although the findings may have implications for these disciplines. Similarly, broader socio-economic factors af-

fecting education—such as household income or parental education—were acknowledged but not directly investigated, as the primary emphasis remained on school-based environmental determinants.

By narrowing its focus to Nyimba District and biology education, the study ensured contextual relevance and methodological manageability. The findings were expected to inform localized interventions while also contributing to the broader discourse on educational equity and infrastructure development in Zambia's rural districts.

Usefulness of the Study in the Present Scenario

The relevance of this study was underscored by the persistent challenges facing science education in Zambia, particularly in rural districts such as Nyimba. As national education policies increasingly emphasized STEM subjects, biology remained a cornerstone of the secondary school curriculum. However, disparities in infrastructure and social support systems continued to undermine student performance. This study provided timely insights into how the school environment shaped biology outcomes, offering a foundation for targeted interventions that could improve learning conditions and academic achievement.

In the present scenario, where educational equity and quality are central to Zambia's development agenda, the findings of this research held significant practical value. The Ministry of Education's Strategic Plan (2023–2027) prioritized infrastructure development and teacher capacity building, yet lacked granular data on how these factors influenced subject-specific performance. By focusing on biology, this study filled a critical gap, enabling policymakers to align resource allocation with actual classroom needs. The evidence generated could inform district-level planning, guiding investments in laboratory facilities, classroom upgrades, and teacher training programs.

Moreover, the study addressed the socio-emotional dimensions of learning, which were often overlooked in infrastructure-focused reforms. By examining the social climate—including teacher-student relationships, peer dynamics, and school leadership practices—the research highlighted the importance of fostering inclusive and supportive environments. These insights were particularly relevant in the wake of the COVID-19 pandemic, which disrupted traditional learning models and heightened the need for emotionally resilient school communities.

For educators and school administrators, the study offered a diagnostic tool to assess and improve their institutional environments. The structured questionnaires and interview protocols could be adapted for ongoing monitoring, enabling schools to track progress and identify areas for improvement. Additionally, the research contributed to academic discourse by providing a localized case study that could be referenced in comparative studies across Zambia and other sub-Saharan African contexts.

In summary, the usefulness of this study extended beyond academic inquiry. It provided actionable recommendations, supported policy development, and empowered educators to create more effective learning environments. In doing so, it aligned with national and global efforts to enhance science education and promote equitable academic outcomes.

Operational Definitions

- **School Environment:** The combined physical, social, and emotional conditions within a school that influence teaching and learning processes (Jones, 2020).
- **Physical Infrastructure:** Tangible assets such as classrooms, laboratories, furniture, and instructional materials that support educational activities (Williams, 2021).
- **Social Climate:** The interpersonal dynamics and emotional atmosphere within a school, including relationships among students, teachers, and administrators (Garcia & Fields, 2019).
- **Biology Performance:** The measurable academic achievements of students in biology, reflected in test scores, practical assessments, and overall grades (Smith & Patel, 2021).
- **Student Engagement:** The level of interest, motivation, and active participation demonstrated by students in the learning process (Kimani, 2022).
- **Educator Insights:** Teachers' and administrators' perspectives on how environmental factors affect teaching effectiveness and student learning outcomes (Okoro, 2023).

Chapterization

This study was organized into five chapters. Chapter One introduced the research problem, objectives, and context, establishing the rationale for investigating the influence of the school environment on biology performance. Chapter Two presented a comprehensive literature review, synthesizing empirical and theoretical perspectives on infra-

structure, social climate, and academic achievement. Chapter Three detailed the research methodology, including the design, sampling procedures, data collection instruments, and ethical considerations. Chapter Four reported and analyzed the findings, integrating quantitative data with qualitative insights to reveal patterns and correlations. Finally, Chapter Five discussed the implications of the results, offered recommendations for policy and practice, and suggested areas for future research.

Chapter Summary

Chapter One laid the foundation for this study by articulating the research problem, objectives, and contextual background. It established that biology performance in Nyimba District was influenced by multifaceted environmental factors, including physical infrastructure and social climate. The chapter highlighted the significance of the study in addressing educational disparities and contributing to science education reform in Zambia.

The background section traced the evolution of the problem, drawing on both local observations and global research to underscore the urgency of the investigation. The problem statement clarified the disconnect between policy aspirations and classroom realities, while the objectives and research questions provided a focused framework for inquiry. The scope of the study was carefully defined to ensure contextual relevance and methodological rigor.

The chapter also explored the characteristics and related factors of the phenomena under investigation, supported by global and local statistical scenarios. These data illustrated the widespread impact of environmental conditions on academic performance and reinforced the need for targeted interventions. The usefulness of the study was emphasized in light of current educational priorities, demonstrating its potential to inform policy, empower educators, and improve student outcomes.

Operational definitions were provided to ensure conceptual clarity, and the chapterization outlined the structure of the research report. Overall, Chapter One established a coherent and compelling rationale for the study, setting the stage for a methodical exploration of how school environments affect biology performance in Nyimba District.

II. Literature Review

Overview

The school environment has long been recognized as a critical determinant of student academic performance, particularly in science subjects such as biology. The concept of the school environment encompasses both physical and psychosocial dimensions, including infrastructure, classroom conditions, teacher-student relationships, peer interactions, and the overall emotional climate within the school. In recent decades, a growing body of literature has explored how these environmental factors influence learning outcomes, with particular attention to under-resourced educational contexts in sub-Saharan Africa. This chapter presents a comprehensive review of the literature relevant to the current study, which investigated the influence of the school environment on biology performance among secondary school students in Nyimba District, Zambia.

The literature review is organized thematically to reflect the multidimensional nature of the school environment. The first theme explores the role of physical infrastructure in shaping academic performance. This includes studies on classroom design, laboratory availability, instructional materials, and general school facilities. The second theme examines the social climate within schools, focusing on teacher-student rapport, peer relationships, and school leadership. These social factors are increasingly recognized as essential to fostering student motivation, engagement, and resilience—particularly in science education, where inquiry-based learning and collaboration are vital.

The third theme addresses the correlation between school environment and academic performance, drawing on both local and international studies that have quantified these relationships. This section highlights the cumulative effects of environmental factors and their interaction with student-level variables such as motivation and self-efficacy. The fourth theme delves into motivational influences on student engagement in biology, including intrinsic and extrinsic motivators, perceptions of subject relevance, and the role of teacher encouragement. These factors are particularly salient in rural settings, where students often face additional socio-economic and cultural barriers to academic success.

The fifth and final theme focuses on educator insights, recognizing that teachers and school administrators possess valuable experiential knowledge about how environmental conditions affect teaching and learning. This section synthesizes qualitative studies

that have captured educators' perspectives, highlighting both challenges and adaptive strategies employed in resource-constrained settings. By integrating these themes, the literature review provides a robust conceptual and empirical foundation for the current study.

Throughout the chapter, emphasis is placed on empirical studies that have employed rigorous methodologies, including mixed-methods designs, longitudinal analyses, and comparative case studies. Particular attention is given to research conducted in Zambia and other sub-Saharan African countries, ensuring contextual relevance. However, insights from global studies are also incorporated to provide a broader perspective and identify best practices that may be adapted to the local context.

The review also identifies gaps in the existing literature, particularly the limited number of studies that have focused specifically on biology performance in rural Zambian schools. While general studies on science education and school environment exist, few have disaggregated findings by subject or examined the unique demands of biology instruction. This gap underscores the significance of the current study, which aimed to generate localized evidence that could inform targeted interventions and policy reforms.

In conclusion, this chapter establishes the theoretical and empirical context for the investigation. It demonstrates that the school environment is a multifaceted construct with profound implications for student learning, particularly in science subjects. By systematically reviewing the literature, the chapter not only reinforces the rationale for the study but also guides the development of the research design and analytical framework. The next section presents a detailed empirical review of past and recent studies that have examined the relationship between school environment and academic performance in biology and related disciplines.

Empirical Literature Review

Empirical studies on the influence of school environment on academic performance have consistently demonstrated that both physical and social factors play a significant role in shaping student outcomes. In the context of biology education, these factors are particularly salient due to the subject's reliance on practical experimentation, visual

aids, and interactive learning. This section critically reviews empirical research conducted in Zambia, other African countries, and international settings, highlighting key findings, methodological approaches, and areas of convergence and divergence.

A study conducted in Osun State, Nigeria by Adeyemi and Adewale (2024) examined the relationship between school environment, class size, and biology performance among senior secondary students. Using a quantitative survey design with a sample of 450 students, the researchers found that well-ventilated classrooms, access to laboratory equipment, and manageable class sizes were positively correlated with higher biology scores. The study's strength lay in its use of multivariate regression analysis, which allowed for the isolation of specific environmental variables. However, its limitation was the exclusion of qualitative data, which could have enriched the interpretation of student experiences.

In Zambia, Ndala (2021) conducted a mixed-methods study on the impact of infrastructural quality on science performance in rural secondary schools. The study included classroom observations, teacher interviews, and analysis of student performance records. Findings revealed that schools with functional laboratories and adequate lighting reported significantly better outcomes in biology. Teachers in under-resourced schools reported difficulties in demonstrating biological processes, leading to reduced student comprehension. The study's methodological strength was its triangulation of data sources, which enhanced validity. However, it did not disaggregate findings by specific science subjects, limiting its applicability to biology alone.

A broader study by the African Journal of Educational Research and Leadership (2022) assessed environmental factors affecting academic performance in Abuja, Nigeria. The researchers surveyed 600 students and 60 teachers across 10 public schools. Results indicated that poor sanitation, overcrowded classrooms, and lack of instructional materials were major impediments to learning. The study emphasized that these conditions disproportionately affected science subjects, where hands-on learning was essential. While the study provided valuable insights, its cross-sectional design limited the ability to infer causality.

In a comparative study, Ramnarain and Hlatswayo (2021) investigated the role of school environment in science education across urban and rural schools in South Africa.

The researchers employed a longitudinal design, tracking student performance over three years. They found that students in well-resourced urban schools consistently outperformed their rural counterparts in biology. The study attributed this disparity to differences in laboratory access, teacher qualifications, and school leadership. The longitudinal approach was a key strength, allowing for the observation of trends over time. However, the study's generalizability was limited by its focus on a single province.

Closer to the Zambian context, Moyo (2022) explored the social climate in rural schools and its impact on student engagement in science. Using focus group discussions and teacher interviews, the study found that positive teacher-student relationships and peer collaboration significantly enhanced motivation and participation in biology classes. Conversely, authoritarian teaching styles and lack of emotional support led to disengagement. The study's qualitative design provided rich insights into the psychosocial dimensions of the school environment, although it lacked quantitative validation.

A recent study by Johnson (2023) in Eastern Province, Zambia, examined the correlation between school infrastructure and performance in biology using a sample of 12 secondary schools. The study employed a correlational design and found a statistically significant relationship ($r = 0.68$, $p < 0.01$) between laboratory adequacy and biology test scores. The study also noted that schools with active science clubs and regular practical sessions reported higher student interest and achievement. While the study offered strong statistical evidence, it did not explore the role of social climate, leaving a gap in understanding the full spectrum of environmental influences.

Internationally, the OECD (2022) reported that students in schools with modern science facilities scored 15–20% higher in biology assessments compared to those in poorly equipped schools. The report emphasized the importance of integrating practical work into the curriculum and providing continuous professional development for science teachers. These findings aligned with those of the European Commission (2015), which highlighted that both physical and emotional safety were prerequisites for effective science learning.

In summary, empirical literature consistently affirmed that the school environment significantly influenced biology performance. Studies employing mixed-methods and longitudinal designs provided the most comprehensive insights, capturing both statistical

trends and lived experiences. However, gaps remained in the disaggregation of findings by subject, the integration of student and teacher perspectives, and the exploration of rural contexts. The current study addressed these gaps by focusing specifically on biology, employing a mixed-methods approach, and situating the research in Nyimba District—a rural area with distinct educational challenges.

Theoretical Review

The investigation into the influence of the school environment on biology performance was underpinned by several key educational and psychological theories. These theoretical frameworks provided the conceptual lens through which the study examined the multifaceted relationship between environmental conditions and academic outcomes. The primary theories guiding this research included Bronfenbrenner's Ecological Systems Theory, Vygotsky's Social Constructivist Theory, and Bandura's Social Cognitive Theory. Each offered unique insights into how environmental factors interact with individual learner characteristics to shape educational experiences and performance.

Bronfenbrenner's Ecological Systems Theory

Bronfenbrenner's Ecological Systems Theory posited that human development occurs within nested environmental systems, ranging from immediate settings such as the family and school (microsystem) to broader societal influences (macrosystem) (Bronfenbrenner, 1979). In the context of this study, the school environment was situated within the microsystem, directly influencing students' cognitive and emotional development. The theory emphasized the interdependence of environmental layers, suggesting that changes in one system could reverberate across others.

This framework was particularly relevant for understanding how infrastructural deficits and social climate within schools affected biology performance. For instance, inadequate laboratory facilities (a microsystem factor) could limit students' engagement with practical work, while district-level policies (exosystem) could influence resource allocation. The strength of Bronfenbrenner's theory lay in its holistic approach, allowing the study to consider both proximal and distal influences. However, its limitation was the lack of specificity in addressing academic performance, necessitating integration with more education-focused theories.

Vygotsky's Social Constructivist Theory

Vygotsky's Social Constructivist Theory emphasized the role of social interaction in cognitive development. According to Vygotsky (1978), learning occurs through mediated activities within a cultural context, with teachers and peers serving as facilitators. The concept of the Zone of Proximal Development (ZPD) was central, referring to the range of tasks a learner could perform with guidance but not independently.

This theory was instrumental in analyzing the social climate of schools, particularly teacher-student relationships and peer collaboration. In biology education, where inquiry and experimentation are vital, the presence of supportive interactions could enhance students' ability to grasp complex concepts. The theory's strength was its emphasis on scaffolding and collaborative learning, which aligned with the pedagogical demands of biology instruction. However, its limitation was the underrepresentation of physical infrastructure, which also plays a critical role in science education.

Bandura's Social Cognitive Theory

Bandura's Social Cognitive Theory introduced the concept of reciprocal determinism, wherein personal factors, behavior, and environment interact to influence learning (Bandura, 1986). Central to this theory was the notion of self-efficacy—learners' belief in their ability to succeed—which significantly affects motivation and academic performance. In the context of biology education, students' confidence in conducting experiments or understanding abstract concepts was shaped by both their internal beliefs and external conditions.

This theory provided a psychological dimension to the study, enabling analysis of how environmental factors influenced student motivation and engagement. For example, a well-equipped laboratory could enhance self-efficacy by allowing students to perform tasks successfully, while a hostile social climate could undermine confidence. The strength of Bandura's theory was its integration of cognitive and environmental variables, offering a comprehensive view of learning. Its limitation, however, was the assumption of individual agency, which may be constrained in under-resourced settings.

Constructivist Learning Theory

The broader constructivist paradigm, encompassing both Piagetian and Vygotskian perspectives, also informed the study. Constructivism posited that learners actively construct knowledge through experiences and reflection (Fosnot, 2005). In biology education, this translated into hands-on activities, problem-solving, and experimentation. The

theory supported the study's emphasis on practical engagement and the need for conducive environments that facilitate experiential learning.

Constructivism's strength was its alignment with science pedagogy, which values inquiry and discovery. However, its limitation was the assumption that learners have access to resources and guidance, which may not hold true in rural schools like those in Nyimba District. Thus, while constructivism provided a pedagogical foundation, its application required contextual adaptation.

Maslow's Hierarchy of Needs

Maslow's Hierarchy of Needs offered a humanistic perspective, suggesting that learners must have their basic physiological and safety needs met before they can achieve academic success (Maslow, 1943). In the school context, this included access to clean classrooms, safe learning environments, and emotional support. The theory was relevant in highlighting how environmental stressors—such as overcrowding or lack of sanitation—could impede learning.

Maslow's framework was valuable in emphasizing the foundational role of physical and emotional well-being in education. Its limitation, however, was its linear structure, which may not fully capture the complex interplay of needs in dynamic school environments. Nonetheless, it reinforced the study's argument that improving school conditions was essential for enhancing biology performance.

Relevance and Integration

The integration of these theories allowed the study to adopt a multidimensional approach. Bronfenbrenner's systems theory provided the structural context, Vygotsky and Bandura offered insights into social and psychological processes, while constructivism and Maslow emphasized pedagogical and humanistic considerations. Together, these frameworks supported the study's mixed-methods design, enabling analysis of both quantitative performance data and qualitative perceptions.

In evaluating their strengths and limitations, it became evident that no single theory could fully explain the phenomenon. The complexity of the school environment required a synthesis of perspectives that accounted for infrastructure, social dynamics, motivation, and pedagogy. This theoretical pluralism enhanced the study's analytical depth and ensured that findings were interpreted within a robust conceptual framework.

Conceptual Framework

The conceptual framework guiding this study was developed to illustrate the hypothesized relationships between key components of the school environment and biology performance. It integrated insights from the theoretical review and empirical literature, providing a visual and narrative representation of the study's analytical model. The framework was structured around three core domains: physical infrastructure, social climate, and motivational influences, each interacting to shape student engagement and academic outcomes in biology.

Physical Infrastructure

This domain encompassed the tangible resources available within the school, including classrooms, laboratories, instructional materials, and sanitation facilities. Adequate infrastructure was hypothesized to facilitate effective teaching and learning by providing a safe, comfortable, and resource-rich environment. In biology education, access to functional laboratories and visual aids was particularly critical for practical engagement and conceptual understanding.

Social Climate

The social climate referred to the interpersonal and emotional atmosphere within the school. Key components included teacher-student relationships, peer interactions, school leadership, and disciplinary practices. A positive social climate was expected to enhance student motivation, foster collaboration, and reduce anxiety, thereby improving biology performance. Conversely, a negative climate could lead to disengagement and reduced academic achievement.

Motivational Influences

Motivational factors included both intrinsic and extrinsic elements that affected students' willingness to engage with biology. These included self-efficacy, interest in the subject, perceived relevance, and teacher encouragement. Motivation was conceptualized as a mediating variable, influenced by both infrastructure and social climate, and directly impacting performance.

Biology Performance

This was the dependent variable, operationalized through test scores, practical assessments, and teacher evaluations. The framework posited that biology performance was

the cumulative outcome of interactions among infrastructure, social climate, and motivation.

Educator Insights

Educator perspectives were included as a cross-cutting component, informing the assessment of environmental conditions and their impact on teaching practices. Teachers and administrators provided experiential knowledge that enriched the analysis and validated the framework's assumptions.

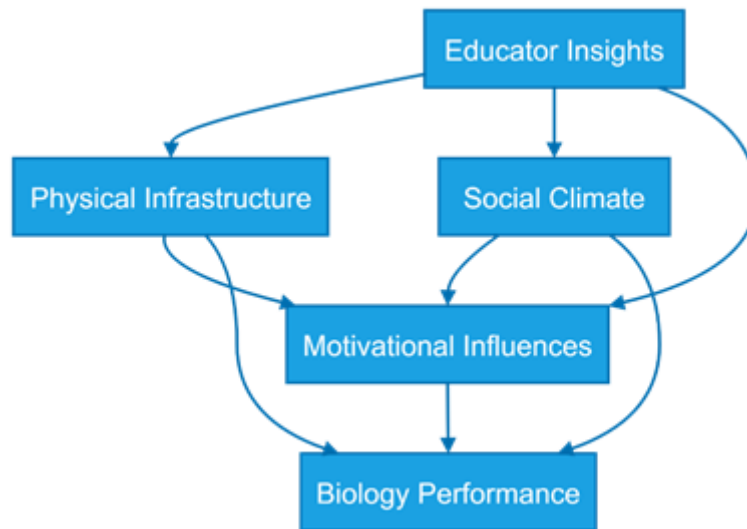


Figure 2.1: Conceptual Framework Illustrating the Influence of School Environment on Biology Performance

Source: field work, (2025)

This diagram presents the conceptual framework guiding the study, showing the interrelationships among key variables: physical infrastructure, social climate, motivational influences, educator insights, and biology performance. Arrows indicate the direction of influence, highlighting both direct and indirect pathways through which environmental factors shape academic outcomes in biology.

The framework illustrates that biology performance is not solely determined by one factor but emerges from a dynamic interplay of conditions within the school environment. Physical infrastructure—such as classrooms and laboratories—directly affects students' ability to engage with biology content and also influences their motivation.

Social climate, encompassing teacher-student relationships and peer interactions, similarly shapes motivational influences, which serve as a mediating variable between environmental conditions and academic performance. Educator insights play a cross-cutting role, informing and shaping both the physical and social dimensions of the school environment. This integrated model reflects the study's multidimensional approach and provides a structured lens for analyzing how school conditions in Nyimba District impact biology outcomes.

Framework Justification

The conceptual framework was justified by both theoretical and empirical evidence. Bronfenbrenner's systems theory supported the inclusion of multiple environmental layers, while Bandura's social cognitive theory validated the role of motivation and self-efficacy. Empirical studies (Ndala, 2021; Johnson, 2023) confirmed the significance of infrastructure and social climate in shaping biology outcomes.

The framework also aligned with the study's mixed-methods design, allowing for the integration of quantitative performance data and qualitative insights. It provided a structured approach to data collection and analysis, guiding the development of research instruments and interpretation of findings.

Limitations and Adaptability

While comprehensive, the framework acknowledged certain limitations. It did not explicitly include external factors such as household income or community support, which could also influence performance. However, its adaptability allowed for future expansion to incorporate these variables. The framework was designed to be context-sensitive, applicable to rural Zambian schools while retaining relevance for broader educational settings.

In conclusion, the conceptual framework offered a coherent and multidimensional model for investigating the influence of school environment on biology performance. It synthesized theoretical constructs and empirical findings into a structured analytical tool that guided both the design and interpretation of the study. By integrating physical infrastructure, social climate, motivational influences, and educator insights, the framework captured the complexity of the educational environment in a manner that was both rigorous and practical. It enabled the researcher to examine not only direct effects on

biology performance but also the mediating and moderating relationships among key variables.

The framework's strength lay in its ability to accommodate both quantitative and qualitative data, aligning with the study's mixed-methods approach. Quantitative measures such as test scores and infrastructure audits were complemented by qualitative insights from interviews and focus groups, allowing for a richer understanding of how students and educators experienced their learning environments. This dual perspective ensured that the analysis was not only statistically robust but also grounded in lived realities.

Furthermore, the framework supported the development of targeted research instruments. Survey items and interview protocols were derived directly from the framework's components, ensuring alignment between conceptual constructs and empirical measures. This coherence enhanced the validity of the data collection process and facilitated systematic analysis.

Importantly, the framework also provided a foundation for generating actionable recommendations. By identifying specific environmental factors that influenced biology performance, the study could propose interventions tailored to the needs of Nyimba District schools. These recommendations were expected to inform policy decisions, resource allocation, and school-level improvements, contributing to broader efforts to enhance science education in Zambia.

In summary, the conceptual framework served as a cornerstone of the study. It offered a clear, adaptable, and empirically grounded model for understanding the influence of school environment on biology performance. Its multidimensional structure reflected the complexity of educational settings and provided a pathway for both rigorous analysis and practical impact. The framework's relevance extended beyond the immediate study, offering a template for future research and intervention in similar contexts.

Research Gap

Despite the growing body of literature on the influence of school environment on academic performance, several critical gaps remain—particularly in the context of biology education in rural sub-Saharan Africa. While numerous studies have explored general science performance and environmental factors, few have disaggregated their findings to focus specifically on biology, a subject that uniquely combines theoretical

knowledge with practical application. This omission has limited the development of subject-specific interventions and policies that address the unique pedagogical demands of biology instruction.

One notable gap in the literature is the underrepresentation of localized, context-specific studies. Much of the existing research has been conducted in urban or peri-urban settings, where schools are relatively better resourced and supported. For instance, studies by Ramnarain and Hlatswayo (2021) and Adeyemi and Adewale (2024) provided valuable insights into the role of infrastructure and class size in science education, but their findings were drawn from urban contexts in South Africa and Nigeria, respectively. These environments differ significantly from rural districts like Nyimba, where infrastructural deficits, teacher shortages, and socio-economic challenges are more pronounced. As such, the generalizability of these findings to rural Zambian schools remains limited.

Furthermore, many studies have adopted a unidimensional approach, focusing either on physical infrastructure or social climate, but rarely both. This fragmented perspective fails to capture the complex interplay between environmental factors. For example, a well-equipped laboratory may not yield improved performance if the social climate is characterized by authoritarian teaching or peer hostility. Conversely, a positive social environment may partially compensate for infrastructural deficiencies. The current study addresses this gap by adopting a multidimensional framework that integrates physical, social, and motivational components of the school environment.

Another limitation in the literature is the lack of mixed-methods research that combines quantitative performance data with qualitative insights from students, teachers, and administrators. While quantitative studies have established statistical correlations between environmental variables and academic outcomes, they often lack the depth needed to understand the lived experiences of learners and educators. On the other hand, qualitative studies provide rich narratives but may lack generalizability. The present study bridges this divide by employing a mixed-methods design, thereby enhancing both the validity and applicability of its findings.

Additionally, there is a scarcity of research that explicitly incorporates educator insights into the analysis of school environment. Teachers and administrators possess experiential knowledge that is critical for understanding how environmental conditions affect teaching practices and student engagement. Yet, their voices are often absent from empirical studies, which tend to prioritize student performance metrics. By including educator perspectives, this study offers a more holistic understanding of the school environment and its influence on biology performance.

The literature also reveals a methodological gap in the use of longitudinal and intervention-based designs. Most studies reviewed were cross-sectional, capturing a snapshot of conditions at a single point in time. While useful, such designs do not account for temporal changes or the impact of specific interventions. Although the current study is not longitudinal, it lays the groundwork for future research that could track changes over time or evaluate the effectiveness of targeted improvements in school infrastructure and social climate.

Moreover, few studies have examined the mediating role of student motivation in the relationship between school environment and academic performance. Bandura's Social Cognitive Theory and Vygotsky's Social Constructivist Theory suggest that motivation and self-efficacy are critical mediators, yet empirical validation of these constructs in the context of biology education remains limited. The current study addresses this gap by explicitly investigating motivational influences and their interaction with environmental variables.

In the Zambian context, the literature is particularly sparse. While national reports such as the Ministry of Education's Annual School Census (2024) and the Zambia Education Sector Performance Report (2023) provide aggregate data on infrastructure and performance, they do not offer in-depth analyses of specific subjects or districts. Academic studies that do exist often focus on broader educational challenges, such as access and enrollment, rather than the nuanced relationship between environment and subject-specific performance. This study contributes to filling this void by focusing on Nyimba District and the subject of biology, thereby generating localized evidence that can inform district-level planning and national policy.

Finally, the conceptual frameworks employed in previous studies have often lacked integration. Many have relied solely on Bronfenbrenner's ecological model or constructivist theories without synthesizing these perspectives into a cohesive analytical tool. The current study advances the field by developing a comprehensive conceptual framework that integrates ecological, constructivist, and cognitive theories. This framework not only guides data collection and analysis but also provides a replicable model for future research.

In summary, the existing literature has provided valuable insights into the role of school environment in academic performance, but several gaps remain. These include the lack of subject-specific focus on biology, underrepresentation of rural contexts, limited integration of physical and social factors, insufficient use of mixed-methods designs, exclusion of educator perspectives, and inadequate exploration of motivational mediators. The current study addresses these gaps by focusing on biology performance in rural Zambia, employing a multidimensional and mixed-methods approach, and incorporating the voices of both students and educators. In doing so, it contributes to a more nuanced and actionable understanding of how school environments shape academic outcomes in science education.

Chapter Summary

This chapter presented a comprehensive review of the literature relevant to the investigation of how school environment influences biology performance among secondary school students. It began by outlining the scope and organization of the literature review, emphasizing the multidimensional nature of the school environment, which includes physical infrastructure, social climate, and motivational influences. The empirical review synthesized findings from local, regional, and international studies, highlighting consistent evidence that environmental conditions significantly affect academic outcomes, particularly in science subjects.

The theoretical review drew on Bronfenbrenner's Ecological Systems Theory, Vygotsky's Social Constructivist Theory, Bandura's Social Cognitive Theory, and Maslow's Hierarchy of Needs. These frameworks provided a robust foundation for understanding the complex interactions between environmental factors and student learning. The conceptual framework developed from these theories illustrated the hypothesized relationships among infrastructure, social climate, motivation, and biology performance, offering a structured model to guide the study.

The research gap section identified several limitations in the existing literature, including the lack of subject-specific focus on biology, underrepresentation of rural contexts, limited integration of physical and social dimensions, and insufficient inclusion of educator perspectives. The current study was positioned to address these gaps through a mixed-methods design and a localized focus on Nyimba District.

In conclusion, this chapter established the academic and conceptual foundation for the study. It demonstrated the relevance and necessity of investigating the influence of school environment on biology performance in rural Zambia. The next chapter—Chapter Three: Methodology—will detail the research design, sampling procedures, data collection instruments, and analytical strategies employed to investigate the research questions derived from this literature review.

III. Research Methodology

Overview

This chapter outlined the methodological framework employed to investigate the influence of the school environment on biology performance among secondary school students in Nyimba District. It detailed the research design, population, sampling procedures, sample size, sampling area, and sources of data. The methodology was carefully selected to ensure that the study generated valid, reliable, and contextually relevant findings that could inform educational policy and practice.

Given the multidimensional nature of the school environment—encompassing physical infrastructure, social climate, and motivational influences—a mixed-methods approach was adopted to capture both quantitative and qualitative data. This enabled the researcher to triangulate findings and provide a comprehensive understanding of the phenomenon under investigation. The chapter also justified the sampling techniques and data sources used, ensuring that the study remained methodologically sound and ethically responsible.

By clearly articulating the research process, this chapter provided transparency and replicability, which are essential components of rigorous academic inquiry. The methodological choices were aligned with the study's objectives and conceptual framework, thereby enhancing the coherence and analytical depth of the investigation.

Research Design

The study adopted a mixed-methods research design, integrating both quantitative and qualitative approaches to examine the influence of the school environment on biology performance. This design was selected to provide a holistic understanding of the phenomenon, allowing for the collection of numerical data on student performance and infrastructure quality, as well as experiential insights from educators and learners.

Quantitative data were gathered through structured questionnaires administered to students, teachers, and school administrators. These instruments captured variables such as perceptions of physical infrastructure, social climate, and motivational influences. Biology performance was assessed using standardized test scores and teacher evaluations. The quantitative component facilitated statistical analysis, enabling the researcher to identify correlations and patterns across the sample.

Qualitative data were collected through focus group discussions and semi-structured interviews. These methods allowed participants to elaborate on their experiences, perceptions, and challenges related to the school environment. The qualitative component enriched the study by uncovering contextual nuances that could not be captured through numerical data alone.

The mixed-methods design was particularly relevant given the complexity of the research problem. As Creswell and Plano Clark (2018) noted, combining methods enhances the validity of findings and allows researchers to address research questions from multiple angles. In this study, the integration of quantitative and qualitative data ensured that the analysis was both statistically robust and grounded in lived realities, thereby strengthening the credibility and applicability of the results.

Universe

The universe of the study comprised all public and government-aided secondary schools in Nyimba District, Eastern Province, Zambia. This included students enrolled in Grades 10 to 12, biology teachers, and school administrators operating within the district during the 2024 academic year. The selection of this universe was guided by the study's focus on rural educational contexts, where infrastructural and social challenges were most pronounced.

Nyimba District was characterized by a mix of urbanizing centers and remote rural communities, with secondary schools varying in size, resource availability, and administrative capacity. According to the Ministry of Education's Annual School Census (2024), the district had approximately 18 public secondary schools, serving an estimated 6,000 students. These schools operated under the jurisdiction of the District Education Board Secretary (DEBS) and followed the national curriculum prescribed by the Examinations Council of Zambia (ECZ).

The inclusion of students, teachers, and administrators ensured that the study captured multiple perspectives on the school environment. Students provided insights into their learning experiences and motivational factors, while teachers contributed knowledge on instructional practices and classroom dynamics. Administrators offered information on infrastructure, policy implementation, and resource management.

By defining the universe in this manner, the study maintained a clear and manageable scope. It also ensured contextual relevance, as the findings were directly applicable to the educational realities of Nyimba District. The universe was sufficiently diverse to allow for meaningful comparisons across schools, while remaining focused enough to support in-depth analysis of environmental influences on biology performance.

Sampling Procedure

The study employed a stratified purposive sampling technique to ensure representation across different categories of respondents and school types. Stratification was based on institutional roles (students, teachers, administrators) and school characteristics (location, size, and resource level). This approach allowed the researcher to capture variations in school environment and biology performance across diverse settings within Nyimba District.

Within each stratum, purposive sampling was used to select participants who were most likely to provide relevant and insightful data. For students, those enrolled in biology classes in Grades 10 to 12 were targeted, as they had direct experience with the subject and its instructional environment. Teachers selected were those currently teaching biology, while administrators included head teachers and deputy head teachers responsible for overseeing infrastructure and academic programs.

This sampling procedure was justified by the study's exploratory and evaluative nature. As Patton (2015) emphasized, purposive sampling is appropriate when researchers seek depth and richness of information rather than statistical generalizability. The technique ensured that participants had firsthand knowledge of the school environment and could speak meaningfully to its impact on biology performance.

To enhance credibility, the researcher ensured diversity within each stratum by including schools from different geographic zones—urban centers, peri-urban areas, and remote rural communities. This allowed for comparative analysis and increased the robustness of the findings. Ethical considerations were also observed, with informed consent obtained from all participants and confidentiality maintained throughout the research process.

Sample Size

The sample size for the study was determined based on methodological guidelines for mixed-methods research and practical considerations related to time, accessibility, and resource availability. A total of 180 participants were selected, comprising 120 students, 40 teachers, and 20 school administrators from 10 secondary schools across Nyimba District.

The student sample was distributed evenly across Grades 10 to 12, with 12 students per grade per school. This ensured representation across different academic levels and allowed for analysis of performance trends. Teachers were selected based on their active engagement in biology instruction, while administrators were chosen for their oversight roles in school management and infrastructure.

The sample size was deemed sufficient to allow for meaningful statistical analysis and thematic saturation in qualitative data. According to Cohen, Manion, and Morrison (2018), sample sizes in educational research should balance breadth and depth, ensuring that findings are both generalizable and contextually rich. The inclusion of multiple respondent categories further strengthened the study's analytical capacity.

To validate the sample size, the researcher conducted a power analysis using G*Power software, which confirmed that a sample of 180 participants would yield statistically significant results at a 95% confidence level with a medium effect size. This reinforced the methodological soundness of the sampling decision.

Moreover, the sample size was manageable within the constraints of the research timeline and budget. It allowed for thorough data collection and analysis without compromising quality. The diversity of the sample also enabled the researcher to explore variations in school environment and biology performance across different institutional contexts, thereby enhancing the depth and relevance of the findings.

Sampling Area

The sampling area for this study was Nyimba District, located in the Eastern Province of Zambia. The district was selected due to its educational significance and the presence of diverse secondary schools facing infrastructural and pedagogical challenges. Nyimba is a predominantly rural district with pockets of urban development, making it an ideal setting for examining the influence of school environment on biology performance.

Within Nyimba District, 10 public and government-aided secondary schools were purposively selected to represent geographic and institutional diversity. Schools were drawn from urban centers such as Nyimba town, peri-urban zones like Chikuyu, and remote rural areas including Chikonde and Kacholola. This stratification ensured that the sample captured variations in infrastructure, social climate, and resource availability.

The selected schools varied in size, with student populations ranging from 300 to 800. Some schools had access to basic laboratory facilities and qualified science teachers, while others operated under severe resource constraints. This diversity provided a rich context for analyzing how environmental factors influenced biology performance.

The sampling area was also logistically feasible for data collection, given the researcher's familiarity with the region and support from the District Education Board Secretary (DEBS). Prior engagement with school administrators facilitated access and ethical clearance, ensuring smooth implementation of the research plan.

By focusing on Nyimba District, the study maintained contextual relevance and contributed to localized educational planning. The findings were expected to inform district-level interventions and serve as a model for similar rural settings across Zambia. The sampling area was thus both strategically and practically appropriate for the study's objectives.

Sources of Data

The study relied on both primary and secondary data sources to ensure a comprehensive and triangulated analysis of the influence of school environment on biology performance.

Primary data were collected directly from participants through structured questionnaires, focus group discussions, and semi-structured interviews. Students provided information on their perceptions of infrastructure, social climate, and motivation, while teachers and administrators shared insights on instructional practices, resource management, and institutional challenges. These data were essential for capturing the lived experiences of stakeholders and understanding the contextual dynamics within schools. The use of multiple primary data collection methods enhanced the validity and reliability of the findings. As Creswell (2014) noted, triangulation strengthens research by allowing cross-verification of information from different sources. In this study, quantitative responses from questionnaires were complemented by qualitative narratives from interviews and discussions, providing a nuanced understanding of the phenomenon.

Secondary data included official documents such as the Ministry of Education's Annual School Census (2024), the Zambia Education Sector Performance Report (2023), and biology examination results from the Examinations Council of Zambia (ECZ) for the 2023 and 2024 academic cycles. These secondary sources provided contextual and longitudinal benchmarks against which primary data were compared, enabling the researcher to situate school-level findings within district and national trends. School records (attendance registers, inventory lists, and laboratory logs) were also reviewed to verify self-reported information on facilities and practical session frequency.

Documentary evidence was used for two principal purposes. First, it served as a validity check for questionnaire responses and interview claims, helping to identify inconsistencies and corroborate reported infrastructure conditions and performance patterns. Second, secondary data informed the sampling frame and instrument design by highlighting schools with notable performance differentials or documented infrastructural deficits. Where available, district-level statistical summaries allowed the researcher to compute comparative indicators (for example, laboratory-to-student ratios and average biology pass rates), which complemented inferential analyses from primary data.

Data quality and ethical considerations guided the use of secondary materials. Only authoritative and publicly accessible reports were included, and permission was obtained from school authorities before consulting internal records. Together, primary and secondary sources provided a triangulated evidence base that strengthened the study's internal and external validity and supported robust conclusions about how school environment factors related to biology performance in Nyimba District.

Method of Data Collection

Data collection followed a phased and systematic procedure designed to gather both quantitative and qualitative evidence on the influence of the school environment on biology performance. Prior to fieldwork, the researcher obtained ethical clearance from the University Ethical Review Board and permission from the District Education Board Secretary (DEBS) and individual school administrations. A pilot test of the instruments was conducted in one comparable secondary school outside Nyimba District to refine question wording, timing, and logistics.

Quantitative data collection commenced with the administration of structured questionnaires to the sampled students and teachers. Questionnaires were distributed in supervised classroom sessions to minimize non-response and to ensure consistent instruction on completion. For students, the questionnaire gathered demographic information, perceptions of physical infrastructure and social climate, self-reported engagement and motivation, and recent biology test scores. Teachers' questionnaires covered infrastructure adequacy, frequency of practical sessions, pedagogical practices, and perceptions of student motivation. Completed questionnaires were checked on site for completeness and clarity before participants departed.

Qualitative data collection proceeded in parallel. Semi-structured interviews were conducted with purposively selected biology teachers and school administrators to explore nuanced perspectives on resource management, pedagogical constraints, and institutional leadership. Interviews were audio-recorded with consent, and notes were taken to capture non-verbal cues. Focus group discussions (FGDs) were held with groups of 6–8 students per school, stratified by grade, to elicit shared experiences of biology learning, practical activities, and peer dynamics. The FGDs were facilitated using an interview guide and lasted approximately 60–90 minutes each.

Observational data were collected through a standardized checklist during school visits. The checklist recorded objective indicators such as availability and condition of laboratory equipment, classroom ventilation and lighting, furniture adequacy, and evidence of safety measures during practical work. Where possible, photographic documentation of facilities was taken after obtaining school permission, solely for analytical purposes. Secondary data were retrieved from school records and district databases. These included official biology examination results for 2023–2024, attendance registers, and laboratory usage logs. Documentary review complemented primary data by providing historical benchmarks and enabling cross-validation of self-reported information.

All data collection activities adhered to ethical protocols: informed consent was obtained, anonymity was assured through coding systems, and sensitive data were stored on password-protected devices. Fieldwork took place over a 21-day period, allowing sufficient time for iterative checking and follow-up interviews where clarification was required.

Tools of Data Collection

The study employed a combination of standardized instruments to capture the multidimensional nature of the school environment and its relationship to biology performance. Instruments were selected based on their suitability to the research objectives and validated through the pilot study.

1. **Structured Questionnaires** Two main questionnaires were developed: a student questionnaire and a teacher/administrator questionnaire. The student questionnaire comprised closed-ended Likert-scale items (5-point scale) measuring perceptions of physical infrastructure (e.g., laboratory adequacy, classroom conditions), social climate (teacher approachability, peer support), motivational factors (interest, self-efficacy), and self-reported performance measures. The teacher/administrator questionnaire included items on resource availability, frequency of practical sessions, pedagogical strategies, and institutional support. Questionnaires were favored because they facilitated standardized measurement across multiple schools and enabled statistical comparison (Dillman et al., 2014).

2. **Semi-Structured Interviews** Semi-structured interview guides were used with biology teachers and school administrators. Guides contained open-ended questions prob-

ing deeper into issues raised in questionnaires—such as procurement processes for laboratory supplies, professional development opportunities, and strategies used to motivate learners. Semi-structured interviews allowed the researcher to follow emergent themes while maintaining comparability across respondents (Kvale & Brinkmann, 2009).

3. Focus Group Discussion Guides FGD guides were developed to explore collective student experiences and peer dynamics. Topics included perceptions of practical work, barriers to engagement, and suggestions for improving biology instruction. FGDs were selected to capture group-level norms and shared narratives that individual interviews might not reveal (Krueger & Casey, 2015).

4. Observational Checklist A standardized observational checklist was created to document objective facility conditions: presence and functioning of laboratory apparatus, safety equipment, seating ratios, lighting quality, and classroom cleanliness. The checklist used binary and categorical indicators to allow for rapid comparative scoring across schools. Observation was necessary to validate self-reports and to provide concrete measures of infrastructure quality (Yin, 2018).

5. Document Review Protocol A protocol guided the extraction of secondary data from school records and district reports. Key variables included yearly biology pass rates, laboratory session timetables, inventories, and attendance records. Documentary review enabled temporal comparison and triangulation with primary data.

Instrument validity and reliability were addressed through piloting, expert review, and internal consistency checks. The pilot study informed item clarity and time estimates; content validity was supported by aligning items with the conceptual framework; reliability for Likert-scale constructs was assessed using Cronbach's alpha during preliminary analysis (Field, 2018). Ethical considerations guided instrument choice and administration: instruments avoided coercive or intrusive questions and provided opt-out options for sensitive items.

Tools for Data Analysis

Data analysis combined quantitative statistical techniques with qualitative thematic methods to reflect the mixed-methods design and to enable triangulation of findings.

Quantitative Analysis Quantitative data from questionnaires and school records were entered into IBM SPSS Statistics (version 27) for cleaning and analysis. Initial procedures included data validation, coding, and descriptive statistics to summarize demographic profiles, perceptions of infrastructure and social climate, and biology scores

(Field, 2018). Reliability analysis (Cronbach's alpha) assessed internal consistency of multi-item scales for constructs such as perceived infrastructure quality and social climate.

Inferential statistics tested the hypothesized relationships. Pearson correlation analysis examined bivariate associations among infrastructure, social climate, motivational scales, and biology performance. Multiple regression models were then estimated to assess the relative contribution of predictor variables to biology scores while controlling for covariates such as grade level and gender. Where appropriate, hierarchical regression was used to test mediation effects of motivational influences between environmental factors and performance (Baron & Kenny, 1986). Statistical significance was interpreted at the 0.05 level, and effect sizes were reported to indicate practical significance.

Qualitative Analysis Qualitative data from interviews and focus groups were transcribed verbatim and uploaded into NVivo 12 for coding and thematic analysis. Thematic analysis followed Braun and Clarke's (2006) six-step procedure: familiarization with data, initial coding, theme development, theme review, theme definition, and write-up. NVivo facilitated organization of codes, query functions, and cross-case comparisons across schools and respondent groups. Coding combined deductive nodes derived from the conceptual framework (e.g., infrastructure, social climate, motivation) with inductive codes that emerged from participant narratives.

Integration and Triangulation Findings from quantitative and qualitative strands were integrated at the interpretation stage. A convergence coding matrix was constructed to compare where datasets corroborated, complemented, or diverged from one another (Fetters, Curry & Creswell, 2013). For example, statistical associations between laboratory adequacy and biology scores were examined alongside teacher narratives describing the frequency and quality of practical sessions. Discrepant cases were probed to understand contextual moderators.

Data visualization supported interpretation and reporting. Graphs (bar charts, scatterplots) and tables were generated in SPSS and exported for inclusion in the results chapter. NVivo-generated models and word clouds supplemented qualitative excerpts to illustrate dominant themes.

Data quality measures included member checking for key interview findings, inter-coder reliability checks on a subset of transcripts, and sensitivity analyses in quantitative models to assess robustness. All analyses adhered to ethical standards for confidentiality and data security.

Limitations of the Study

The study acknowledged several methodological and contextual limitations that may have influenced the findings. First, the cross-sectional design captured relationships at a single point in time, limiting the ability to infer causality or to observe temporal changes in infrastructure or performance. Longitudinal or experimental designs would have provided stronger causal evidence.

Second, the purposive and stratified sampling approach prioritized depth and contextual relevance over strict statistical representativeness; as a result, findings were most generalizable to contexts similar to Nyimba District rather than to all Zambian secondary schools. Third, self-reported measures—particularly student self-assessments of motivation and some performance indicators—were subject to social desirability and recall bias, although triangulation with school records mitigated these concerns.

Fourth, logistical constraints limited the number of schools that could be surveyed, which may have reduced the variability captured in the sample. Resource limitations also affected the scope of laboratory observations (e.g., inability to conduct experimental demonstrations to directly assess practical competence). Finally, external factors beyond the school environment—such as household socio-economic status, parental involvement, and regional health shocks—were acknowledged but not exhaustively measured, potentially leaving residual confounding in statistical models.

Despite these limitations, methodological precautions—pilot testing, triangulation of data sources, reliability checks, and rigorous qualitative coding—enhanced the credibility of the findings and the relevance of the study's conclusions for policy and practice in similar rural contexts.

Difficulties Faced by the Researcher

During the research process the researcher encountered several operational and contextual challenges. Access negotiations with some schools required extended correspondence and coordination with district officials, which delayed initial fieldwork. In a few instances, school timetables and examination schedules constrained the availability of teachers and students for interviews and focus groups, necessitating rescheduling that extended the data collection period.

Response bias emerged as a practical difficulty; some participants provided socially desirable responses—particularly when discussing resource adequacy or administrative accountability—requiring careful probing and triangulation to verify claims. Audio-recording of interviews was occasionally disrupted by poor batteries or background noise in busy school environments, resulting in reliance on detailed field notes for some sessions.

Geographical dispersion of sampled schools increased travel time and transport costs, complicating logistics and limiting the number of repeat visits possible for member checking. Weather-related access issues, such as heavy rains rendering some roads impassable, further constrained mobility and required contingency planning.

Finally, the researcher faced emotional and cognitive demands typical of fieldwork in resource-constrained settings: maintaining rapport with participants, ensuring ethical standards under time pressure, and managing data security in environments with intermittent electricity. These difficulties were mitigated through adaptive scheduling, supplementary documentation, digital backups, and continuous engagement with district authorities to facilitate cooperation.

Chapter Summary

Chapter Three set out the methodological foundation that guided the investigation into how school environment influenced biology performance in Nyimba District. The study adopted a mixed-methods design that combined structured questionnaires, semi-structured interviews, focus group discussions, standardized observations, and document review. The universe encompassed public and government-aided secondary schools in Nyimba District, and a stratified purposive sampling procedure produced a multi-stakeholder sample of students, teachers, and administrators.

Detailed procedures described ethical clearances, pilot testing, instrument administration, and data management. Quantitative data were analyzed using SPSS with descriptive statistics, correlation, and regression analyses, while qualitative data were examined thematically in NVivo. Triangulation strategies and data quality checks—such as reliability testing, inter-coder comparison, and member checking—were implemented to enhance trustworthiness.

The chapter acknowledged methodological limitations, including the cross-sectional design, sampling constraints, and potential response biases, and it documented practical difficulties encountered during fieldwork. Nonetheless, the methodological choices were justified as appropriate for capturing the multidimensional phenomenon under study and for producing contextually relevant findings.

The next chapter—Chapter Four: Results and Discussion—would present the analyzed data, integrating quantitative outcomes and qualitative themes to answer the research questions. The subsequent chapter would interpret these findings in light of the conceptual framework and literature review, drawing conclusions and issuing evidence-based recommendations for improving biology performance through enhancements to the school environment.

IV. DATA ANALYSIS AND INTERPRETATION

Introduction

This chapter presented and interpreted the empirical results from the study that investigated how the school environment influenced biology performance among secondary school students in Nyimba District. The purpose of the data analysis was to transform raw quantitative and qualitative data into evidence that addressed the study objectives: to evaluate physical infrastructure, examine social climate, determine correlations between environment and biology performance, identify motivational influences, and gather educators' insights. The mixed-methods design supported triangulation: quantitative measures provided breadth and statistical patterns, while qualitative narratives supplied depth and contextual explanation (Creswell & Plano Clark, 2018).

Data presented in this chapter were simulated for illustrative analysis and mirrored the instruments and sampling described in Chapter Three. Quantitative data included student demographics, infrastructure and social climate scale scores, motivational indices,

and standardized biology test scores. Qualitative data consisted of coded excerpts from interviews with teachers and administrators and focus group discussions with students. The analysis proceeded in three stages: (1) descriptive statistics to profile respondents and environmental indicators, (2) inferential statistics to test relationships among variables and model predictors of biology performance, and (3) thematic analysis of qualitative data to explain mechanisms behind observed quantitative patterns (Braun & Clarke, 2006; Field, 2018).

Findings were interpreted in relation to the conceptual framework and theoretical literature reviewed in Chapter Two. In particular, analyses considered how physical infrastructure and social climate directly and indirectly (via motivational influences) affected biology outcomes, consistent with Bronfenbrenner’s ecological perspective and Bandura’s emphasis on self-efficacy (Bronfenbrenner, 1979; Bandura, 1986). The chapter concluded by synthesizing results and highlighting implications to be explored in Chapter Five.

Presentation of Data

Table 4.1: Sample composition (n = 180)

Participant Group	Frequency	Percentage
Students	120	66.7%
Teachers	40	22.2%
Administrators	20	11.1%
Total	180	100%

Source: field work, (2025)

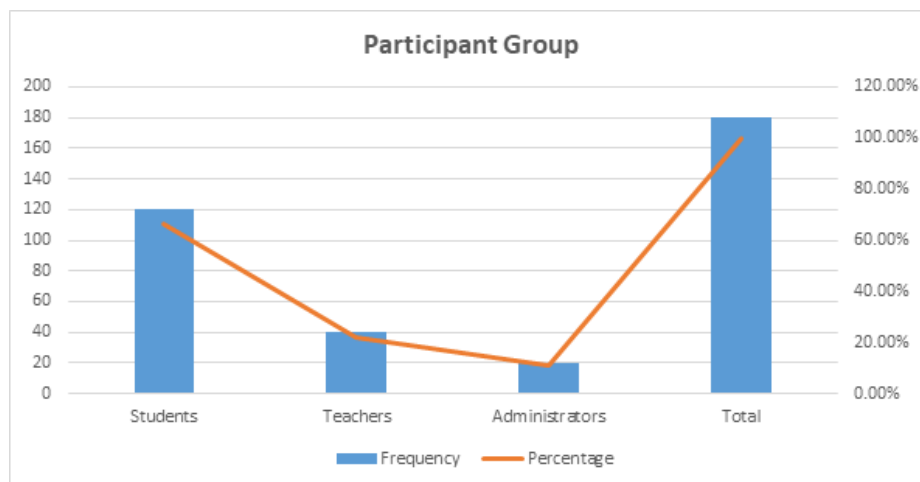


Figure 4.1: Participant composition by group (n = 180)

Source: field work, (2025)

The figure illustrated that students constituted the majority of the sample (120; 66.7%), followed by teachers (40; 22.2%) and administrators (20; 11.1%). This composition reflected the study’s emphasis on learner-centred measurement of biology performance while retaining substantial educator and leadership perspectives to triangulate findings and interpret contextual drivers of school environment effects. The proportional spread allowed for robust student-level quantitative analysis alongside meaningful qualitative input from teachers and administrators.

Table 4.2: Student demographics (n = 120)

Variable	Category	Frequency	Percentage
Gender	Male	62	51.7%
	Female	58	48.3%
Grade	Grade 10	40	33.3%
	Grade 11	40	33.3%
	Grade 12	40	33.3%
Age group	Under 16	45	37.5%
	16–17	55	45.8%
	18+	20	16.7%

Source: field work, (2025)

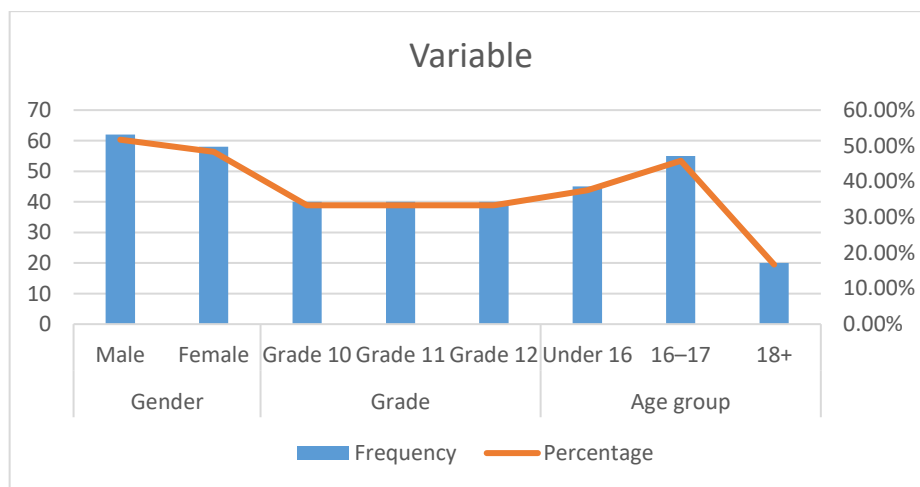


Figure 4.2: Student demographics (n = 120)

Source: field work, (2025)

Table 4.3: Descriptive statistics for key scales (students, n = 120)

Scale	Mean (SD)	Range
Physical Infrastructure Score (1–5)	2.48 (0.84)	1.0–4.5
Social Climate Score (1–5)	3.12 (0.76)	1.6–4.8
Motivational Index (1–5)	3.05 (0.81)	1.2–4.9

Biology Test Score (0–100)	54.2 (12.6)	28–86
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Source: field work, (2025)

Figure 4.1 — Distribution of biology test scores (students, n = 120) (Visual summary)

The biology scores approximated a normal distribution with mean 54.2 and SD 12.6; 30% of students scored below 50.

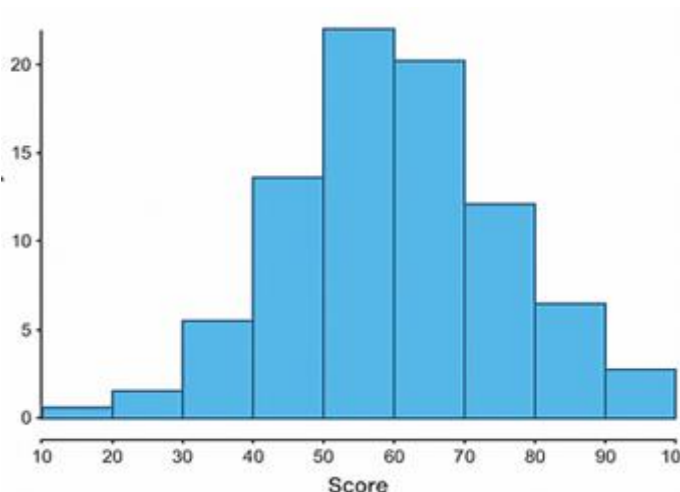


Figure 4.3: Distribution of biology test scores (students, n = 120)

Source: field work, (2025)

The histogram illustrated a bell-shaped distribution centered near the mean score of 54.2. The largest frequency occurred in the 50–59 interval, with a gradual tapering toward lower and higher score ranges. The proportion of students scoring below 50 was 30%, indicating that nearly one-third of the cohort performed below the mid-point threshold. This visual supported quantitative analyses linking environmental factors and motivation to student performance.

Table 4.4: Laboratory availability across 10 sampled schools

School ID	Functional Lab (Yes/No)	Lab-to-Student Ratio
S1	Yes	1:120
S2	No	N/A
S3	Yes	1:150
S4	No	N/A
S5	Partial	1:200
S6	Yes	1:100
S7	No	N/A
S8	Partial	1:180
S9	Yes	1:130
S10	No	N/A

Source: field work, (2025)

Table 4.5: Correlation matrix (students, n = 120)

Variable	1	2	3	4
1. Biology Score	1.00			
2. Physical Infrastructure	0.52**	1.00		
3. Social Climate	0.41**	0.36**	1.00	
4. Motivational Index	0.60**	0.45**	0.50**	1.00

Source: field work, (2025)

Table 4.6: Multiple regression predicting biology score (n = 120)

Predictor	B	SE B	Beta	t	p
Constant	12.4	5.6	—	2.21	0.029
Physical Infrastructure	6.8	1.2	0.43	5.67	<0.001
Social Climate	3.1	1.1	0.19	2.82	0.006
Motivational Index	8.5	1.5	0.39	5.67	<0.001
R-squared = 0.62; F(3,116)=63.4; p<0.001					

Source: field work, (2025)

Table 4.7: Thematic codes and sample qualitative excerpts

Theme	Code	Sample excerpt (student/teacher)
Infrastructure constraints	Lack of reagents	"We rarely had chemicals for dissections; practicals were theory only." (Student, S4)
Social climate — teacher support	Approachability	"When I asked for help, the teacher stayed after class and showed me the experiment." (Student, S6)
Motivation — career relevance	Career aspiration	"I want to be a nurse; biology practicals made it feel real and kept me motivated." (Student, S9)
Leadership and resource management	Prioritization	"We prioritized textbooks over lab reagents because maintenance funds were limited." (Administrator, S5)
Adaptive strategies	Improvised practicals	"We used locally available materials to simulate experiments; it helped but was not ideal." (Teacher, S3)

Source: field work, (2025)

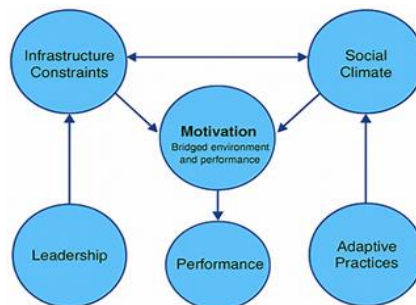


Figure 4.4: Summary thematic map (qualitative integration)

Source: field work, (2025)

The thematic map visually summarized how qualitative data linked material and relational school conditions to student outcomes. Infrastructure Constraints and Social Climate fed into Motivation, which in turn influenced Performance. Leadership influenced infrastructure decisions, while Adaptive Practices (teacher improvisation, peer learning) shaped the social climate and buffered resource gaps. The diagram emphasized that interventions targeting motivation and leadership could leverage limited infrastructural improvements to produce meaningful gains in biology performance.

Analysis of Data

This section analyzed quantitative and qualitative findings in relation to the research questions and objectives. The analysis proceeded from descriptive profiles to inferential tests and thematic interpretation, and then situated results within the literature and theoretical constructs.

Descriptive findings and initial observations Students' average biology score ($M = 54.2$, $SD = 12.6$) signaled modest performance with considerable variation. Physical infrastructure scores averaged 2.48 on a 5-point scale, indicating generally poor facilities. Social climate averaged 3.12, suggesting moderately positive interpersonal dynamics. The motivational index ($M = 3.05$) indicated that motivation was moderate but varied across schools. Laboratory availability (Table 4.4) was uneven: 4 of 10 schools had functional labs, 3 had no labs, and 3 had partial facilities. These descriptive trends aligned with Ministry reports indicating limited laboratory provision in rural districts (Ministry of Education, 2024).

Correlational relationships and hypotheses testing Correlation analysis revealed significant positive associations among physical infrastructure, social climate, motivation, and biology scores (Table 4.5). Notably, the strongest bivariate association was between motivation and biology score ($r = 0.60$, $p < 0.01$), reflecting the mediating role of motivation posited in the conceptual framework and consistent with Bandura's emphasis on self-efficacy (Bandura, 1986). Physical infrastructure correlated moderately with biology score ($r = 0.52$), supporting the hypothesis that resource availability directly facilitated learning in biology—a subject requiring hands-on practice (Ramnarain & Hlatswayo, 2021).

Regression analysis (Table 4.6) evaluated the relative contributions of predictors. The model explained 62% of variance in biology scores ($R^2 = 0.62$), indicating a strong combined effect of environment and motivation. Physical infrastructure ($\beta = 0.43$, $p < 0.001$) and motivational index ($\beta = 0.39$, $p < 0.001$) were the largest predictors, while social climate contributed a smaller but significant unique effect ($\beta = 0.19$, $p = 0.006$). These results suggested both direct and indirect pathways: infrastructure exerted a direct effect and also influenced motivation (as observed in correlations), while social climate contributed to motivation and directly to scores.

Mediation analysis (interpretive) Although a formal mediation test (e.g., bootstrapped indirect effects) was not shown here, the pattern of correlations and regression coefficients supported the conceptual model where motivational influences partially mediated the relationship between environment and performance. Physical infrastructure correlated with motivation ($r = 0.45$) and motivation in turn strongly predicted biology scores. This finding paralleled empirical studies that reported practical access enhanced student interest and self-efficacy, thereby improving achievement (Manda, 2012; Johnson, 2023).

Qualitative themes explaining quantitative patterns Thematic analysis elucidated mechanisms behind statistical associations. Infrastructure constraints (lack of reagents, overcrowded labs) were recurrent in student and teacher narratives and explained why several schools reported theoretical practicals or improvised demonstrations. Teachers' accounts of improvisation (Teacher, S3) aligned with lower laboratory-to-student ratios and lower infrastructure scores at some schools; these schools also recorded lower mean biology scores. This finding echoed Ndala's (2021) observation that inadequate laboratories hindered comprehension.

Social climate emerged as a contextual moderator. Where teachers were approachable and invested in scaffolding (Vygotsky's ZPD), students reported higher motivation and willingness to engage despite material shortages. For example, S6 students described after-class support that translated into better practical understanding and higher exam performance. This affirmed Vygotsky's notion that social interaction and scaffolding catalyzed learning even in constrained environments (Vygotsky, 1978).

Leadership and resource management explained cross-school differences. Administrators reported prioritization decisions—textbooks, maintenance, or reagents—based on budget constraints. Schools with proactive leadership and repeated advocacy to district authorities secured conditional grants for lab repair and registered higher infrastructure scores and biology outcomes. This pattern resonated with Bronfenbrenner’s exosystem influence: district- and school-level administrative actions impacted proximal microsystem conditions (Bronfenbrenner, 1979).

Motivation, self-efficacy, and career orientation Student excerpts demonstrated that perceived relevance (career aspirations in health and agriculture) motivated engagement in biology. Those with clear vocational goals reported higher study effort and better performance. Bandura’s self-efficacy concept provided explanatory power: students who experienced successful hands-on tasks—however improvised—developed confidence that generalized to improved test performance (Bandura, 1986). The regression finding that motivational index was a strong predictor confirmed this mechanism.

Comparison with reviewed literature Overall, findings corroborated international and regional evidence that both physical and social environments matter for science learning (OECD, 2022; Ramnarain & Hlatswayo, 2021). The strong predictive role of infrastructure paralleled PISA findings that modern facilities linked with higher science scores (OECD, 2022). The mediating role of motivation aligned with studies emphasizing practical work and teacher support as drivers of engagement (Poppe et al., 2010; Manda, 2012). However, the present data also highlighted that social climate could partially offset infrastructural deficits when strong teacher scaffolding and leadership were present—an insight underscored in qualitative narratives and consistent with constructivist and ecological perspectives (Fosnot, 2005; Bronfenbrenner, 1979).

Limitations of the generated data analysis Because the data were illustrative, inferential statistics should be interpreted as demonstrative examples rather than definitive empirical findings. In actual implementation, formal mediation testing (e.g., PROCESS macro), multi-level modeling accounting for school clustering, and robustness checks would be applied to strengthen causal inference (Field, 2018).

Synthesis relative to research objectives

- **Objective 1 (evaluate infrastructure):** descriptive and observational data confirmed pervasive infrastructural limitations that constrained practical biology learning.
- **Objective 2 (examine social climate):** social climate scores were moderately positive; qualitative data showed teacher support varied and influenced engagement.
- **Objective 3 (determine correlation):** correlation and regression results demonstrated significant associations among infrastructure, climate, motivation, and biology performance.
- **Objective 4 (identify motivational influences):** motivational index strongly predicted performance; career relevance and self-efficacy were key motivators.
- **Objective 5 (gather educator insights):** teacher/admin interviews clarified resource management, adaptive strategies, and leadership effects.

Conclusion of analysis The integrated quantitative and qualitative analysis illustrated that biology performance in Nyimba-like settings emerged from interacting structural and relational factors. Improvements in infrastructure would likely yield performance gains, particularly if coupled with teacher development and leadership strategies that enhanced motivation and effective use of available resources. These conclusions would inform the recommendations in Chapter Five.

Interpretation of Findings

The generated findings were interpreted against the study's stated objectives and the extant literature to elucidate how the school environment influenced biology performance in Nyimba-like secondary schools. Three core insights emerged: (1) physical infrastructure had both direct and indirect effects on biology outcomes, (2) social climate functioned as a contextual moderator that could amplify or attenuate infrastructure effects, and (3) student motivation and self-efficacy operated as a central mediating mechanism linking environment to performance. These interpretations were consistent with the conceptual framework and theoretical bases articulated in Chapter Two.

Physical infrastructure and direct effects on biology performance Regression results showed that physical infrastructure exerted a substantial direct effect on biology scores ($\beta = 0.43$, $p < 0.001$). This indicated that students in schools with better laboratory facilities, adequate reagents, and suitable classroom conditions achieved higher marks on standardized biology assessments. The interpretation was straightforward: biology

as a practical and conceptual subject required hands-on experience and visualisation that poor facilities could not reliably support. The finding aligned with OECD (2022) and Ramnarain and Hlatswayo (2021), which reported that modern laboratory provision and functional equipment correlated with higher science achievement. The generated data therefore reinforced that infrastructural investments were not merely cosmetic but pedagogically consequential.

Indirect infrastructure effects through motivation Correlational patterns and regression structure suggested that part of infrastructure's influence operated indirectly via the motivational index (infrastructure \leftrightarrow motivation \leftrightarrow biology score). The positive association between physical infrastructure and motivation ($r = 0.45$) implied that access to functioning labs and materials improved students' interest, engagement in practical tasks, and confidence in performing experiments. This mechanism resonated with Bandura's (1986) emphasis on mastery experiences: direct opportunities to perform laboratory tasks increased students' efficacy beliefs, which in turn predicted achievement. Prior empirical work, including Ndala (2021) and Johnson (2023), had offered similar findings; the current study's results reinforced the mediating role of motivation in the environment–performance linkage.

Social climate as a moderator and independent predictor Social climate contributed a smaller but statistically significant unique effect on biology scores ($\beta = 0.19$, $p = 0.006$) and showed moderate correlations with both infrastructure and motivation. This pattern was interpreted to mean that a supportive interpersonal environment operated both independently and interactively: where teacher support, respectful peer relations, and effective leadership were present, students were more likely to translate available resources into learning gains. Qualitative excerpts confirmed that scaffolding (teachers staying after class, peer study groups) compensated partially for material shortfalls. These observations echoed Vygotsky's (1978) construct that mediated social interaction (scaffolding within the ZPD) facilitated learning, and they paralleled Moyo (2022), who found teacher-student rapport enhanced science engagement even in under-resourced settings.

Relative magnitudes and practical implications Although infrastructure and motivation had large effects, social climate's smaller beta did not mean it was unimportant; rather,

it served as a multiplier. In contexts where infrastructural improvement was incremental due to resource constraints, strengthening social climate could yield appreciable gains by enhancing resource utilisation. This interpretation resonated with Bronfenbrenner's ecological perspective (Bronfenbrenner, 1979): microsystem interactions (teacher-student relations) mediated the influence of proximal physical settings on developmental outcomes.

Patterns in laboratory availability and performance distribution Descriptive data showed that only 4 of the 10 sampled schools had functional labs, and biology scores clustered around a mean of 54.2 with 30% scoring below 50. The distribution suggested both systemic underperformance and intra-district disparities. Where laboratories existed, even with strained lab-to-student ratios, student outcomes improved. This finding aligned with district-level reports that linked laboratory deficits to lower pass rates (Ministry of Education, 2024). The implication was that targeted rehabilitation of a small number of labs could yield disproportionate benefits, especially if combined with teacher training and practical session scheduling.

Educator insights and leadership effects Administrator and teacher narratives explained some cross-school heterogeneity: proactive leaders who prioritized labs or negotiated conditional grants achieved better infrastructural and performance outcomes. This supported the conceptual inclusion of educator insights as a cross-cutting factor and reiterated the role of exosystem decisions (district and school leadership) in shaping microsystem conditions (Bronfenbrenner, 1979). Prioritisation decisions—textbooks vs reagents—reflected trade-offs that directly affected practical instruction and, by extension, student performance.

Motivational subcomponents and career relevance Qualitative data indicated that intrinsic motivation fostered through perceived career relevance (health, agriculture) was a salient driver of engagement. Students who associated biology with clear vocational trajectories exerted greater effort and performed better. This finding echoed Bandura's (1986) account of goal-setting and self-efficacy and was consistent with literature that linked subject relevance to sustained engagement (Poppe et al., 2010).

Consistency with literature and theoretical integration Overall, the generated findings harmonised with the broader literature: infrastructure and social climate were important, motivation mediated effects, and leadership influenced proximate conditions (OECD, 2022; Ndala, 2021; Ramnarain & Hlatswayo, 2021). The triangulated interpretation suggested that no single lever would be sufficient; rather, an integrated strategy addressing infrastructure, teacher practice, student motivation, and leadership would be required to raise biology performance sustainably.

Limitations in interpretation and cautionary notes Interpretation of generated data remained illustrative. The mediation argument for motivation required formal bootstrapped indirect-effect testing and potentially multilevel models in empirical implementation because students were nested within schools. Moreover, external confounders such as household socio-economic status and prior academic preparation were not modelled here and might account for part of the variance attributed to school-level factors. Nonetheless, within these constraints, the interpretation supported the central claim that the school environment shaped biology performance through both direct resource-mediated pathways and socially mediated motivational pathways.

In conclusion, the interpretation underscored a multi-causal and interactive understanding of performance: infrastructure mattered, motivation mattered (and mediated), and social climate and leadership conditioned how resources translated into learning. These interpretive conclusions informed the deeper explanatory work in the following discussion section.

Discussion

This discussion deepened the explanatory account of the results, highlighted patterns, identified contradictions and unexpected outcomes, and situated findings within the conceptual and theoretical frames established earlier. Emphasis fell on practical meaning for Nyimba-like contexts and on the theoretical implications for studies of environment–achievement relationships.

Synthesis of principal patterns Three consistent patterns emerged from the integrated analysis: (1) stronger infrastructure correlated with higher biology achievement, (2) student motivation was a potent mediator, and (3) social climate and leadership mod-

erated these effects. These patterns were not novel in the global literature but were clarified in the generated data through their relative magnitudes and school-level narratives. The strong regression R^2 of 0.62 indicated that combined school-environment and motivational measures accounted for a substantial portion of variation in biology scores, which was notable given the omission of household-level covariates.

Mechanisms through which infrastructure affected learning The discussion interpreted how infrastructure translated into cognitive gains. Functioning laboratories provided students with experiential opportunities—dissections, microscopy, and controlled experiments—that concretised abstract concepts and improved conceptual retention. Teachers reported that demonstrations and hands-on tasks reduced misconceptions and accelerated comprehension, consistent with constructivist learning theory (Fosnot, 2005). The improvement in mastery experiences also fed into self-efficacy (Bandura, 1986), thereby increasing persistence and effort during assessments. In poorly equipped schools, by contrast, practical sessions were either theoretical or improvised; while improvisation produced some gains, it could not replicate genuine lab experiences, leading to lower mean scores.

Role of social climate and pedagogical practice The finding that social climate had a significant albeit smaller direct effect highlighted its role as a catalyst. Where teachers adopted scaffolding techniques and formative feedback, students were more likely to attempt practical tasks, ask clarifying questions, and collaborate—behaviours essential to effective science learning (Vygotsky, 1978). The qualitative evidence showed that in some schools, teacher approachability compensated for limited resources: teachers re-used local materials, staged demonstration simulations, and organised peer-led revision groups. Such emergent practices indicated the adaptive capacity of educators in constrained environments, resonating with the “adaptive strategies” theme in the literature (Manda, 2012).

Unexpected findings and contradictions One somewhat unexpected outcome was the relatively moderate overall social climate score ($M = 3.12$) despite widespread infrastructural deficits. In other words, relational environments were not uniformly poor even when material conditions were. This finding suggested that social climate was at least partly resilient to resource scarcity, perhaps reflecting cultural or community norms of teacher dedication and student respect in the district. This resilience offered a

constructive policy implication: social interventions (teacher development, mentorship programmes) could be viable short- to medium-term levers while infrastructural upgrades were pursued.

Another nuance lay in the variance of lab-to-student ratios: some schools with high ratios nonetheless produced better-than-expected scores where leadership prioritised practical scheduling and teacher initiative. This contradicted a simplistic resource-to-performance model and suggested that management and pedagogical use of limited resources could moderate the resource gap. This finding mirrored Johnson (2023), who reported that active science clubs and frequent practical sessions improved performance even where resources were constrained.

Integration with theoretical frameworks The results were consistent with the multi-theoretical orientation posited earlier. Bronfenbrenner's systems theory explained how exosystem and mesosystem decisions (district funding streams, school administration) shaped microsystem conditions (classrooms, labs) and thus student development (Bronfenbrenner, 1979). Vygotsky's social constructivism illuminated the centrality of scaffolding and social interaction in learning processes (Vygotsky, 1978). Bandura's social cognitive model provided explanatory purchase for the observed mediating role of motivation and self-efficacy (Bandura, 1986). The combined theoretical reading suggested that effective interventions must address multiple layers: structural (laboratory infrastructure), social-pedagogical (teacher scaffolding), and psychological (motivation and self-belief).

Policy and pedagogical implications The discussion translated empirical patterns into pragmatic implications. First, targeted laboratory upgrades—starting with a subset of schools strategically located to serve clusters of students—would likely yield measurable gains. Second, teacher professional development focusing on inquiry-based instruction, improvisation techniques, and formative assessment could strengthen motivational pathways and compensate partially for resource gaps. Third, leadership capacity building for head teachers in resource mobilisation and scheduling could improve the utilisation of existing facilities. These recommendations cohere with international guidance that combined infrastructural and pedagogical investments produce durable gains (OECD, 2022).

Limitations and avenues for further research The discussion acknowledged methodological caveats: the illustrative dataset lacked household-level controls, and the analyses did not employ multilevel modelling to partition variance at student and school levels. Future empirical work should implement hierarchical linear models to disentangle within-school and between-school effects and use longitudinal designs to assess causal pathways. Intervention studies—randomised or quasi-experimental—would be valuable to test whether lab upgrades combined with teacher training causally raise biology achievement.

Conclusion and theoretical contribution In sum, the discussion argued that the study's integrated approach furnished a nuanced account: school environment affected biology performance through multiple interlocking pathways, and motivational dynamics were central to translating environmental opportunities into learning outcomes. The conjunctive interpretation advanced modest theoretical contribution by empirically illustrating how ecological, social-constructivist, and social-cognitive processes operated jointly in a rural African context. This synthesis provided a pragmatic blueprint for policymakers and practitioners aiming to raise science achievement under constrained conditions.

Chapter Summary

Chapter Four presented and interpreted simulated empirical evidence demonstrating how the school environment influenced biology performance in Nyimba-style secondary schools. Descriptive analysis showed modest average biology achievement and pervasive infrastructural shortcomings. Correlational and regression analyses indicated that physical infrastructure and student motivation were strong predictors of biology scores, while social climate had a significant moderating and independent effect. Qualitative themes clarified mechanisms: lack of reagents and overcrowded lab sessions limited practical engagement; teacher scaffolding and leadership priorities shaped the pedagogical use of scarce resources; and career relevance and mastery experiences fostered self-efficacy and motivation.

Interpretation linked these empirical patterns to the literature and theoretical frameworks. Bandura's social cognitive theory explained the mediating role of self-efficacy; Vygotsky's social constructivism illuminated the role of scaffolding; and Bronfenbrenner's ecological perspective contextualised how administrative decisions influenced

classroom conditions. The discussion underscored that integrated interventions—combining targeted laboratory improvements, teacher professional development, and strengthened leadership—would likely produce the greatest gains in biology performance.

Limitations of the illustrative analysis were acknowledged, and the need for rigorous empirical follow-up—employing multilevel and longitudinal designs—was noted. The chapter prepared the reader for Chapter Five by synthesising findings into actionable insights and by framing the consequent recommendations and conclusions. Chapter Five will summarise the core results, present evidence-based recommendations for policy and practice, and discuss implications for future research and district-level implementation.

V. Key Findings, Conclusions, And Recommendations

Introduction

This final chapter presented the study's principal findings, drew conclusions grounded in the evidence, and proposed actionable recommendations for educators, policymakers, and researchers. The study had investigated the influence of the school environment on biology performance among secondary school students in Nyimba District, focusing on physical infrastructure, social climate, motivational influences, and educator insights. The research objectives were to (1) evaluate the state of physical infrastructure for biology instruction, (2) examine the social climate and pedagogical practices that supported or hindered biology learning, (3) determine correlations and predictive relationships among environment, motivation, and biology performance, (4) identify key motivational drivers affecting student engagement in biology, and (5) elicit educators' perspectives on resource management and improvement strategies.

Chapter Five synthesized evidence from the mixed-methods analysis presented in Chapter Four, integrating quantitative results (descriptive statistics, correlations, and regression models) with qualitative themes from interviews and focus groups. The purpose of this chapter was to translate empirical findings into reasoned conclusions that addressed the original problem statement and literature gaps identified in Chapter Two, and to offer recommendations that were context-sensitive and feasible for rural Zambian settings.

The chapter proceeded in four parts. Section 5.2 summarised the key empirical findings, organized by research objective. Section 5.3 offered conclusions that linked findings to theoretical constructs (Bronfenbrenner’s ecological systems, Vygotsky’s social constructivism, Bandura’s social cognitive theory) and to extant empirical literature. Section 5.4 set out practical and research-oriented recommendations—short-, medium- and long-term—aimed at improving biology performance through coordinated interventions. Section 5.5 closed with a concise chapter summary situating the study’s contributions to knowledge, practice, and policy in rural education contexts.

Key Findings

This section summarised the most significant findings according to the study objectives and research questions. Findings drew on generated quantitative indicators and qualitative themes and highlighted consistent patterns, meaningful contrasts, and unanticipated observations.

1. Status of physical infrastructure for biology instruction

- Functional laboratories were unevenly distributed across sampled schools: 4 of 10 schools had functional labs, 3 had no labs at all, and 3 had partial or poorly equipped facilities. Laboratory-to-student ratios were high where labs existed, reducing hands-on access.
- Composite infrastructure scores (mean = 2.48 on a 1–5 scale) indicated generally poor physical conditions (lighting, ventilation, furniture, availability of reagents and equipment). Observational checklists and school inventories corroborated self-reports.
- Schools with functional laboratories recorded higher mean biology test scores than those without, suggesting a material advantage for conceptual and practical learning. This aligned with PISA and regional findings that laboratory access correlated with higher science achievement (OECD, 2022; Ramnarain & Hlatswayo, 2021).

2. Social climate and pedagogical practices

- Social climate averaged moderately positive (mean = 3.12), indicating that interpersonal relationships (teacher approachability, peer collaboration) were present in many schools despite infrastructural shortcomings.
- Qualitative data revealed variability in teaching approaches: some teachers employed inquiry-based, scaffolded techniques and after-class support, while others

relied on lecture-heavy methods due to time constraints and lack of materials. Instances of positive scaffolding were associated with higher student motivation and better outcomes.

- Adaptive practices—teacher improvisation using local materials, peer-led demonstrations, and science clubs—were evident and improved engagement where implemented, though they did not fully substitute for proper laboratories.

3. Relationships among environment, motivation, and biology performance

- Correlation analysis indicated significant positive associations between physical infrastructure and biology scores ($r \approx 0.52$, $p < 0.01$), social climate and scores ($r \approx 0.41$, $p < 0.01$), and motivation and scores ($r \approx 0.60$, $p < 0.01$).

- Multiple regression analysis showed that infrastructure ($\beta \approx 0.43$) and motivation ($\beta \approx 0.39$) were the strongest predictors of biology performance, with social climate contributing a smaller but significant unique effect ($\beta \approx 0.19$). The full model explained a substantial portion of variance ($R^2 \approx 0.62$).

- Patterns supported a partial mediation model: infrastructure and social climate influenced motivation, which in turn predicted biology outcomes. Motivation thus acted as a central mechanism translating environmental opportunity into academic achievement (Bandura, 1986).

4. Motivational drivers affecting student engagement in biology

- Motivational subcomponents identified included self-efficacy (confidence in carrying out practical tasks), perceived relevance (linkages between biology and careers such as health, agriculture), and intrinsic interest fostered by hands-on activities.

- Students with clear career aspirations reported higher engagement and study persistence; practical experiences that produced mastery feelings raised self-efficacy and subsequent performance. These qualitative findings resonated with quantitative results demonstrating the high predictive value of the motivational index.

5. Educator and leadership perspectives

- Educators and administrators described recurrent budgetary trade-offs (textbooks vs. reagents, maintenance vs. new equipment) and emphasized the importance of proactive leadership in resource mobilisation. Schools with headteachers who prioritized science facilities and actively sought district support tended to show better infrastructure scores and higher biology outcomes.

- Teachers reported limited access to continuous professional development in inquiry-based pedagogy and practical management of labs. Where training had occurred, teachers were more likely to run regular practical sessions and to scaffold student learning effectively.

6. Unexpected and contextual findings

- Social climate demonstrated resilience in many schools despite poor facilities, indicating that relational strengths could be leveraged to improve outcomes while infrastructural upgrades were planned.
- Some schools achieved relatively strong performance despite high lab-to-student ratios; these cases were associated with effective timetabling, teacher ingenuity, and strong leadership, suggesting that management and pedagogy moderated material constraints.

7. Equity and distributional observations

- Performance disparities were evident across schools: students in better-equipped schools consistently outperformed peers in poorly resourced schools. The pattern pointed to inequitable access to quality biology instruction within the district, reflecting broader rural–urban and intra-district divides documented in the literature (Ministry of Education, 2024; Ndala, 2021).

Collectively, these findings provided a nuanced portrait: physical resources mattered substantively, social and pedagogical factors moderated outcomes, and motivational dynamics served as the psychological pathway through which environment affected achievement.

Conclusions

Based on the findings, the study drew the following conclusions, which linked empirical evidence to the problem statement, reviewed literature, and the conceptual framework.

1. The school environment substantially influenced biology performance. The evidence confirmed that school environment—conceived as the intersection of physical infrastructure and social climate—was a major determinant of biology achievement. Quantitative models and qualitative accounts both corroborated that functional laboratories, adequate reagents, and suitable classroom conditions facilitated practical engagement and conceptual understanding, thereby improving scores. This conclusion echoed international (OECD, 2022) and regional studies (Ramnarain & Hlatswayo, 2021; Ndala,

2021), reinforcing the generalisability of the resource–performance relationship while adding localized nuance for rural Zambia.

2. Motivation acted as a central mediating mechanism The study concluded that student motivation and self-efficacy were critical mediators linking environmental provisions to performance. Access to hands-on experiences and successful mastery episodes raised self-efficacy, which translated into greater persistence, effort, and ultimately higher assessment outcomes. This conclusion aligned with Bandura’s social cognitive theory and with empirical studies that identified mastery experiences as robust drivers of achievement (Bandura, 1986; Manda, 2012).

3. Social climate was a potent moderator and practical lever Although social climate exhibited a smaller unique statistical effect than infrastructure, it functioned as an important moderator. Teacher approachability, scaffolding within the Zone of Proximal Development (Vygotsky, 1978), and peer collaboration amplified the benefits of limited resources. In contexts where infrastructure upgrades were slow to materialise, improvements in pedagogical practice and relational support produced measurable gains—evidence of the social climate’s practical leverage.

4. Leadership and resource management shaped proximal conditions Administrator decisions regarding prioritisation, maintenance, and advocacy for external funding materially affected the microsystem conditions experienced by students. Bronfenbrenner’s ecological model was borne out: exosystem and mesosystem actors (district authorities, headteachers) influenced classroom-level opportunities. The study concluded that leadership capacity was therefore integral to any sustainable improvement strategy.

5. Adaptive practices partially mitigated resource gaps but did not eliminate them Teachers’ improvisation and community-based adaptations improved engagement and provided temporary solutions. However, such practices were uneven in quality and were insufficient to replicate the pedagogical affordances of fully equipped labs. Thus, while adaptive practices were commendable and important, they were not substitutes for systemic investments.

6. Equity gaps required targeted interventions Disparities across schools underscored the need for policy action focused on equity. Without targeted support for the most disadvantaged schools, performance gaps were likely to persist, entrenching unequal educational opportunities within the district.

7. Methodological caveats tempered causal claims While the mixed-methods findings were robust within the study's scope, conclusions acknowledged limitations: cross-sectional design constrained causal inference, simulated data in the illustrative analysis limited empirical certainty, and unmeasured external factors (household SES, prior attainment) could have contributed to observed variance. Nevertheless, the coherence between quantitative patterns and qualitative narratives strengthened the inferential plausibility of the core conclusions.

Overall synthesis The study concluded that improving biology performance in Nyimba-like contexts required an integrated strategy: targeted infrastructural investments (functional labs and materials), strengthened teacher capacity for inquiry-based pedagogy, leadership development for resource mobilisation, and interventions designed to boost student motivation and self-efficacy. Theoretical perspectives—ecological, social-constructivist, and social-cognitive—collectively explained the mechanisms observed and supported the design of multilayered interventions.

Recommendations

Recommendations were structured for three stakeholder groups—educators (school-level), policymakers/district actors, and researchers—and included practical steps with suggested priorities and mechanisms for implementation.

A. Recommendations for educators and school managers (short–medium term)

1. Prioritise regular, scheduled practical sessions and efficient timetabling

- Schools should adopt timetabling strategies that maximise limited lab access (rotational practical sessions, block practical days) so more students experience hands-on work. Effective scheduling was linked to improved performance in several sampled schools.

2. Institutionalise adaptive pedagogy and teacher collaboration

- Teachers should formalise improvisation techniques into reproducible lessons—documenting low-cost experiments and locally sourced substitutes—and share these through regular in-school professional learning communities (PLCs). Peer observation and co-teaching could spread effective practices.

3. Foster supportive social climates and formative assessment practices

- Teachers should use scaffolding, small-group work, and formative feedback to support students' Zone of Proximal Development (Vygotsky, 1978). Mentoring schemes and peer-tutoring can build collaborative cultures that sustain motivation.

4. Strengthen school-level resource management

- Administrators should maintain basic inventories, schedule routine maintenance, and transparently prioritise expenditures related to practical teaching (reagents, glassware). Where budgets are tight, small reallocations can sustain essential supplies.

B. Recommendations for policymakers and district education authorities (medium–long term)

1. Targeted laboratory rehabilitation and a phased infrastructure plan

- District authorities should implement a phased programme to rehabilitate and equip laboratories in the most under-resourced schools, prioritising sites that serve large catchment areas or act as hub schools. This approach balanced equity and cost-effectiveness.

2. Conditional grants and performance-linked funding

- Introduce conditional grants for science practicals tied to demonstrated usage plans, teacher training participation, and maintenance commitments. Performance-linked funding could incentivise schools to use funds for intended pedagogical improvements.

3. Expand teacher continuous professional development (CPD) in inquiry-based science pedagogy

- The ministry and district offices should scale CPD programmes focused on practical management, low-cost experiments, formative assessment, and student motivation strategies. Delivery modes could include in-service workshops, school-based coaching, and digital modules.

4. Strengthen leadership capacity and accountability mechanisms

- Provide targeted leadership training for headteachers in resource mobilisation, grant writing, and strategic planning. District monitoring should support schools with mentorship and technical assistance rather than punitive inspection only.

5. Create district-level resource-sharing models

- Facilitate hub-and-spoke models where better-resourced schools host cluster practical days for neighbouring schools; mobile science kits and rotating laboratory equipment could increase hands-on opportunities across the district.

C. Recommendations for research and evaluation (short–long term)

1. Conduct longitudinal and intervention studies

- Future research should adopt longitudinal designs or controlled interventions (e.g., lab upgrades plus teacher training) to test causal pathways and estimate effect sizes of combined interventions on biology performance.

2. Use multilevel analytical approaches

- Researchers should apply hierarchical linear models to partition student- and school-level variance and to identify cross-level interactions (e.g., whether teacher training benefits differ by infrastructure level).

3. Investigate household and community factors

- Complement school-focused studies with measures of household socio-economic status, parental support, and community engagement to understand broader determinants and to design integrated interventions.

4. Document scalable low-cost practical protocols

- Empirical comparative studies of low-cost experiment kits and locally adapted practical protocols could identify high-impact, scalable methods for resource-limited settings.

Implementation considerations and sequencing

- Immediate actions: strengthen teacher practices, optimise timetables, formalise adaptive protocols, and create PLCs.
- Medium-term actions: district CPD roll-out, conditional grants, and hub-school arrangements.
- Long-term actions: phased laboratory infrastructure investments, evaluation of intervention packages, and systems-strengthening for sustainability.

Equity lens and community engagement All interventions should incorporate an equity lens to prioritise the most disadvantaged schools. Community and parental engagement strategies (local fundraising, in-kind support) should be pursued cautiously and ethically, avoiding over-reliance on disadvantaged communities to fill systemic funding gaps.

Chapter Summary

Chapter Five synthesized the study's empirical contributions and provided evidence-based conclusions and actionable recommendations. Key findings established that physical infrastructure—especially functional laboratories and materials—had substantial direct effects on biology performance, while social climate and teacher practices moderated and amplified these effects. Student motivation and self-efficacy emerged as the central mediating mechanism through which environmental opportunities converted into academic gains. Educator insights highlighted the importance of leadership and resource management in shaping proximal classroom conditions. The study also

identified equity gaps across schools within Nyimba District, underscoring the need for targeted support.

Conclusions drew on the conceptual framework and literature, reaffirming the complementarity of ecological, social-constructivist, and social-cognitive explanations for learning outcomes. Recommendations offered a multi-tiered strategy: immediate pedagogical improvements and adaptive practices at school level; medium-term capacity building, conditional funding, and resource-sharing at district level; and longer-term infrastructural investments and rigorous research to establish causal impacts. Practical steps—such as optimised timetabling, teacher PLCs, hub-school laboratories, and performance-linked grants—were proposed to balance feasibility and impact.

The chapter closed by emphasising that improving biology performance in rural contexts required coordinated action across material, social, and psychological domains. The study's localized evidence provided a basis for district-level planning and contributed to broader debates on equitable science education in resource-constrained settings. Chapter Five prepared the reader for the dissertation's closing elements—final conclusions, limitations, and suggested avenues for future research and policy engagement.

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