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Assessing Technology Integration in Ordinary Level Chemistry Education: A case of Chipadze High School

By

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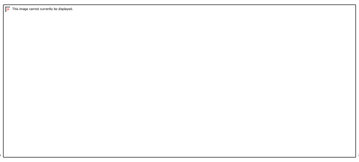
Approval Form

The undersigned certify that they have supervised the student in the research dissertation entitled, "Assessing Technology Integration in Ordinary Level Chemistry Education: A case of Chipadze High School" submitted in partial fulfillment of the requirements for a Diploma in Science Education at Bindura University of Science Education.



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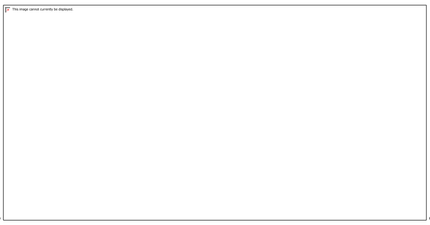

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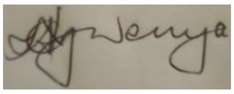

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Dedication

This dissertation is dedicated with heartfelt gratitude to my husband and to my parents, Mr. and Mrs. Kamito, whose steadfast faith in me and continuous support have been a source of strength throughout this journey. Your dedication and encouragement have been instrumental in making this accomplishment a reality. I also extend this dedication to all future Biology students—may you be inspired to persevere and reach your highest potential despite any obstacles.

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I am profoundly grateful to God Almighty for the strength, wisdom, and good health that enabled me to complete this research project. My sincere appreciation goes to my research supervisor, whose consistent guidance, support, and encouragement played a vital role in the successful completion of this study. I am also deeply thankful to my beloved husband, parents, and siblings whose unwavering faith in me and your continuous support have been invaluable. May you be richly blessed.

Abstract

This study investigated the integration of Information and Communication Technology (ICT) in the teaching and learning of Ordinary Level Chemistry at Chipadze High School in Bindura, Zimbabwe. Grounded in the interpretivist paradigm, the research employed a case study design using a predominantly qualitative approach supported by descriptive statistics. Data were collected through semi-structured interviews with Chemistry teachers and structured questionnaires administered to Form 3 and Form 4 students.

The study aimed to examine the types of educational technologies currently in use, identify the key barriers hindering effective ICT integration, and explore the perceived impact of technology on student engagement and learning outcomes. Findings revealed that ICT usage was limited and largely dependent on personal devices such as smartphones, with minimal access to specialized Chemistry software or institutional digital infrastructure. Significant challenges were identified, including inadequate resources, insufficient teacher training, unreliable electricity and internet access, and lack of institutional support.

Despite these challenges, both teachers and students expressed positive perceptions of ICT's potential to enhance conceptual understanding and student motivation when properly implemented. The study concludes that while policy support for ICT exists, effective integration remains constrained by contextual realities on the ground. It recommends targeted interventions including context-specific professional development, improved infrastructure, and policy alignment at the school level to bridge the gap between policy intentions and classroom practice.

List of Abbreviations

Abbreviation	Full Term
ICT	Information and Communication Technology
O' Level	Ordinary Level
MoPSE	Ministry of Primary and Secondary Education
TPACK	Technological Pedagogical Content Knowledge
TAM	Technology Acceptance Model
ZIMSEC	Zimbabwe School Examinations Council
ZPD	Zone of Proximal Development
STEM	Science, Technology, Engineering and Mathematics

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CHAPTER 1: INTRODUCTION AND PROBLEM SETTING

1.1 Introduction

The pervasive influence of Information and Communication Technology (ICT) marks the 21st century, fundamentally altering societal structures, economic models, and, crucially, educational paradigms (Nikolić et al., 2019). In this digital age, education systems globally are increasingly tasked with not only imparting subject knowledge but also cultivating digital literacy and competencies essential for lifelong learning and active participation in a knowledge-based economy (Ghavifekr, Afshari and Amla, 2012). Educational technology, encompassing a range of digital tools, resources, and associated pedagogical strategies, offers transformative potential to meet these demands by enhancing the quality, accessibility, and effectiveness of teaching and learning processes (AECT, 2008; Grabe, 2007).

Within the specific domain of science education, particularly Chemistry at the secondary level, technology integration holds unique promise. Chemistry often presents pedagogical challenges due to its abstract nature, reliance on visualizing microscopic processes, and the need for safe, repeatable experimentation (Kennedy and Odell, 2014). Educational technologies, such as interactive simulations, virtual laboratories, molecular modeling software, and data-logging tools, can effectively address these challenges, providing dynamic visualizations, facilitating inquiry-based learning, and allowing students to engage with complex concepts in ways not possible through traditional methods alone (Hillmayr et al., 2020; Centre for the New Economy and Society, 2018).

This study focuses on assessing the current state of technology integration in the teaching and learning of Chemistry at the Ordinary Level (O' Level) using Chipadze High School in Bindura District, Zimbabwe as a case study. While national policies may advocate for ICT adoption, the realities of implementation at the school level, particularly concerning resource availability, teacher capacity, and pedagogical alignment, require thorough investigation. Understanding how technology is, or is not, being effectively leveraged in O' Level Chemistry at Chipadze High School is essential for identifying strengths, diagnosing challenges, and ultimately informing targeted strategies to enhance educational quality and student outcomes in this critical subject area. This chapter establishes the context, outlines the research problem, and details the objectives, questions, and scope guiding this assessment.

1.2 Background to the Study

The global educational landscape has shifted significantly with the proliferation of ICT. International bodies and national governments alike emphasize the need for educational systems to adapt, leveraging technology to foster 21st-century skills such as critical thinking, collaboration, creativity, and digital literacy (UNESCO, 2011; World Economic Forum, 2018). The integration of technology is no longer viewed merely as an optional enhancement but as a fundamental component of quality education, essential for preparing students for higher education, the workforce, and engaged citizenship in an increasingly digital world (Jameson et al., 2013). This involves more than simply providing devices; it necessitates a pedagogical shift towards learner-centred approaches where technology is used purposefully to deepen understanding, promote active learning, and cater to diverse student needs (Armseth and Hatlevik, 2012).

In the context of STEM education, the rationale for technology integration is particularly compelling. Subjects like Chemistry involve concepts operating at multiple levels (macroscopic, microscopic, symbolic) and require students to develop both conceptual understanding and practical skills. Traditional methods, while valuable, can struggle to adequately convey dynamic processes or provide sufficient safe opportunities for experimentation. Educational technologies specifically designed for science offer powerful affordances: interactive simulations allow exploration of variables and 'what-if' scenarios impossible in a physical lab; virtual labs provide access to sophisticated equipment and procedures without cost or safety constraints; animations can vividly illustrate molecular interactions; and digital probes enable real-time data collection and analysis, fostering scientific inquiry skills (Olympiou and Zacharia, 2012; Rutten et al., 2012; Hillmayr et al., 2020). Research consistently indicates that, when integrated effectively, these tools can significantly improve students' conceptual understanding, problem-solving abilities, and motivation in science subjects (Ronen and Eliahu, 2011; Smetana and Bell, 2012).

Within Zimbabwe, the commitment to leveraging ICT in education is formally articulated in national policies. The Ministry of Primary and Secondary Education's (MoPSE) ICT Policy for Primary and Secondary Education (2019–2023), for instance, outlines strategic objectives focused on developing ICT infrastructure, enhancing connectivity, building teacher capacity through training, promoting the development and use of digital content, and integrating ICT across the curriculum (Ministry of Primary and Secondary Education, 2019). This policy framework reflects an understanding of ICT's potential role in modernizing the education system and aligning it with regional and global trends.

However, translating policy aspirations into effective classroom practice faces significant hurdles, particularly in resource-constrained environments common in many parts of Zimbabwe. Consistent challenges reported in the literature include inadequate infrastructure (shortage of functional computers, limited or unreliable internet access, inconsistent electricity supply), insufficient technical support, a lack of appropriate digital content aligned with the national curriculum, and large class sizes that make individualized technology use difficult (Chidzonga et al., 2022; Maupa and Goronga, 2023; Shava, 2022).

Furthermore, while teacher training programs often include ICT components, questions remain about their effectiveness in equipping teachers with not just basic digital literacy but also the pedagogical competence to integrate technology meaningfully into their specific subject areas, like Chemistry (Abel et al., 2022; Makuru and Jita, 2022). Teacher attitudes, beliefs about technology's role in learning, and confidence levels also play a critical role in determining the extent and nature of ICT adoption in classrooms (Ertmer and Ottenbreit-Leftwich, 2010).

Chipadze High School, situated in Bindura District, Mashonaland Central Province, operates within this broader national context. As a government secondary school providing education up to O' Level, it serves a diverse student population and is subject to the opportunities and constraints outlined in national educational policies and resource allocations. Understanding the specific ways technology is being integrated into O' Level Chemistry teaching and learning at Chipadze – the types of tools available and used, the frequency and nature of their use, the training and support provided to teachers, and the perceived challenges and benefits – requires a focused assessment. This study, therefore, aims to provide an in-depth, context-specific analysis of technology integration within this particular school setting, contributing valuable empirical data to the broader understanding of ICT in Zimbabwean education.

1.3 Statement of the Problem

While national policies advocate for ICT integration and its potential benefits for subjects like O' Level Chemistry are theoretically clear, the practical reality at the school level often falls short. At Chipadze High School, anecdotal evidence and preliminary observations suggest that the integration of technology into the teaching and learning of O' Level Chemistry is inconsistent and faces significant obstacles. There is concern that potential benefits – such as improved visualization of abstract chemical concepts (e.g., molecular bonding, reaction mechanisms), enhanced student engagement through interactive simulations, access to wider learning resources, and development of digital literacy skills – are not being fully realized.

Specific issues contributing to this problem may include, Limited Access and Infrastructure, Teacher Capacity and Training, Curriculum Alignment and Lack of Assessed Impact. Without a systematic assessment of the current technology integration landscape for O' Level Chemistry at Chipadze High School, it is difficult to identify the precise nature and extent of these challenges, pinpoint successful practices that could be scaled, or develop targeted, evidence-based interventions. This lack of clarity impedes efforts to optimize resource allocation, tailor professional development, and ultimately improve the quality and effectiveness of Chemistry education through appropriate technology integration.

1.4 Research Aim

The main aim of this study is to assess the integration of technology in the teaching and learning of Chemistry at the Ordinary Level at Chipadze High School.

1.5 Research Objectives

The study is guided by the following objectives:

- To examine the types of educational technology (hardware, software, online resources) currently available and actively employed in O’ Level Chemistry classrooms at Chipadze High School.
- To investigate the primary barriers—including technical, pedagogical, institutional, and attitudinal—faced by teachers and students in effectively utilizing technology for O’ Level Chemistry instruction.
- To analyze the perceived impact of current technology integration practices on student engagement, motivation, conceptual understanding, and overall learning outcome in O’ Level Chemistry at Chipadze High School.

1.6 Research Questions

The study seeks to answer the following key questions:

- What types of educational technology are currently used in O' Level Chemistry classrooms at Chipadze High School?
- What are the key barriers to the effective integration and use of technology in the teaching and learning of O' Level Chemistry at Chipadze High School?
- What are the teachers and students perceptions on the impact of technology integration on student engagement and learning outcomes in O' Level Chemistry?

1.7 Significance of the Study

The findings from this assessment of technology integration in O' Level Chemistry at Chipadze High School are anticipated to hold significant value for multiple stakeholders:

Chemistry Teachers: This study will provide teachers at Chipadze and potentially other similar schools with practical insights into which technologies are being used, how they are being implemented, and the real-world challenges encountered. Understanding common barriers and potentially successful strategies employed by peers can inform their own teaching practices and highlight specific needs for professional development (Abel et al., 2022).

Students: By identifying technologies and pedagogical approaches that enhance engagement and understanding in Chemistry, the study can indirectly contribute to improving students' learning experiences. Understanding student perspectives on technology use can also help tailor instruction more effectively (Hillmayr et al., 2020).

School Administration (Chipadze High School): The assessment will offer concrete, evidence-based information crucial for strategic planning. This includes guiding decisions on ICT infrastructure investment, prioritizing resource allocation for the Chemistry department, identifying needs for technical support, and designing relevant in-house or external teacher training initiatives (Ministry of Primary and Secondary Education, 2019).

Curriculum Developers & Ministry of Education (MoPSE): This research provides valuable ground-level data illustrating the practicalities, challenges, and successes of implementing national ICT policies within a specific school context. Such empirical evidence can inform the refinement of future ICT policies, curriculum guidelines for Chemistry, and the development of national support structures and digital resources (Centre for the New Economy and Society, 2018).

Teacher Training Institutions & Educational Researchers: The study contributes empirical data to the broader field of educational technology, particularly concerning ICT integration in science education within developing country or low-resource contexts. The findings can inform the design of pre-service and in-service teacher training programs, making them more relevant to the challenges teachers face, and can also identify areas for future, more extensive research (Roblyer and Doering, 2013).

1.8 Delimitations of the Study

The scope of this study is deliberately confined to investigating the teaching and learning of Chemistry at the Ordinary Level (Forms 3 and 4) in a single-case context. By focusing exclusively on O' Level Chemistry, the research does not extend to other science disciplines or non-science subjects. All data are drawn from Chipadze High School in Bindura, Zimbabwe, and involve only those Chemistry teachers and students who were enrolled in Forms 3 and 4 during the study period. While this narrow focus allows for an in-depth exploration of ICT integration in Chemistry instruction within this particular setting, it also means that the findings may not be readily generalizable to schools operating under different contextual, demographic, or resource conditions.

1.9 Limitations of the Study

The researcher recognizes that, as a single-site case study, the insights generated may not readily transfer to other secondary schools across Zimbabwe, each of which may differ in terms of infrastructure, staffing, and institutional culture. Although the in-depth focus on Chipadze High School yields rich contextual understanding, these very particulars constrain the broader applicability of the findings.

Moreover, the study's temporal boundaries pose another limitation: data gathered over a relatively short period may fail to reflect how technology integration practices develop and mature over time. Consequently, any long–term effects on teaching approaches or student outcomes might remain undetected within this snapshot of practice. Practical considerations around time and financial resources further shape the research design. For instance, the number of classroom observations conducted had to be balanced against these constraints, potentially limiting the diversity and volume of observed teaching–learning interactions.

Finally, the reliance on self-reported data—via questionnaires and interviews with teachers and learners—introduces an element of subjectivity. Participants' recollections and responses may be influenced by personal biases or the desire to present themselves in a favorable light. In addition, given the rapid evolution of educational technologies, the specific tools and platforms examined during this study may soon be replaced or updated, which could lessen the enduring relevance of certain conclusions and recommendations.

1.10 Definition of Key Terms

For the purpose of this study, the following key terms are defined operationally as:

Technology Integration: The systematic and pedagogically informed use of Information and Communication Technology (ICT) tools, digital resources, and associated practices.

Assessment (of Technology Integration): The investigative process central to this study, involving the systematic collection, analysis, and evaluation of data concerning the types, usage patterns, perceived effectiveness, impacts, and challenges related to educational technology within the O' Level Chemistry context at Chipadze High School.

Educational Technology: The application of technological tools (hardware, software, networks), resources, and pedagogical principles to support and enhance teaching and learning processes. This includes, but is not limited to, computers, tablets, projectors, interactive whiteboards, educational software (simulations, virtual labs), online learning platforms, and digital content repositories (based on AECT, 2008).

Ordinary Level (O' Level) Chemistry: Refers specifically to the Chemistry syllabus designed for Forms 3 and 4 in the Zimbabwean secondary education system, as mandated and examined by the Zimbabwe School Examinations Council (ZIMSEC).

Student Engagement: The multifaceted involvement of students in their Chemistry learning, characterized by behavioural participation (e.g., attending, completing tasks), cognitive investment (e.g., effort, strategy use), and emotional connection (e.g., interest, enthusiasm), particularly in relation to technology-mediated activities (Fredricks et al., 2004).

Learning Outcomes: Explicit statements detailing the specific knowledge (e.g., understanding chemical principles), skills (e.g., problem-solving, data interpretation), and attitudes that students are expected to acquire or demonstrate following instruction, particularly through experiences involving educational technology in the O' Level Chemistry course.

1.11 Organization of the Study

This dissertation is structured into five distinct chapters:

Chapter 1: Introduction and Problem Setting: Provides the overall context, background information, articulates the research problem, specifies the aim, objectives, and research questions, discusses the study's significance, outlines its boundaries (delimitations) and potential limitations, defines key operational terms, and presents the organizational structure of the entire document.

Chapter 2: Literature Review: Examines existing scholarly literature relevant to technology integration in education, focusing specifically on science and Chemistry teaching at the secondary level. It explores theoretical frameworks, documented benefits, prevalent challenges (technical, pedagogical, institutional), the role of teacher factors (training, attitudes), and the Zimbabwean ICT policy context.

Chapter 3: Research Methodology: Details the methodological approach employed in the study. This includes justification for the research paradigm and approach. The case study research design, the target population and sampling strategy, the data collection instruments, procedures for data generation and analysis, and measures taken to ensure ethical conduct and trustworthiness of the findings.

Chapter 4: Data Presentation, Analysis, and Interpretation: Presents the findings derived from the data collected at Chipadze High School. This chapter organizes the data according to the research questions and themes, utilizes appropriate methods for qualitative analysis and interprets the results in relation to the literature reviewed in Chapter 2.

Chapter 5: Summary, Conclusions, and Recommendations: Provides a concise summary of the entire study, draws conclusions based directly on the analysis of the findings in relation to the research objectives, discusses the implications of the results, offers practical recommendations for stakeholders (teachers, administration, policymakers), and suggests potential avenues for future research.

1.12 Chapter Summary

This foundational chapter has delineated the research territory by introducing the critical area of technology integration assessment within O' Level Chemistry education. It situated the study within global and national educational trends, highlighted the specific potential and challenges of

ICT in Chemistry, and pinpointed the research problem as it pertains to Chipadze High School. The chapter clearly articulated the study's specific aim, objectives, and guiding questions. Furthermore, it underscored the relevance and potential contributions of the research for key stakeholders, while carefully outlining the study's scope through its delimitations and acknowledging inherent limitations. Essential terminology was operationally defined to ensure consistent understanding, and a road-map for the subsequent chapters was provided. This comprehensive introduction sets a clear direction for the literature review presented in Chapter 2.

CHAPTER 2: LITERATURE REVIEW

2.0 Introduction

The ubiquitous integration of Information and Communication Technology (ICT) has irrevocably altered the landscape of modern education, presenting both unprecedented opportunities and complex challenges for educators and institutions worldwide. This chapter undertakes a comprehensive review of the scholarly literature concerning the critical issue of teacher preparedness for integrating ICT within the specific domain of Ordinary Level (O' Level) Chemistry education. While drawing upon global research, the review places particular emphasis on understanding the context within Zimbabwe and environments similar to the study site, Chipadze High School. The necessity for such a review stems from the increasing policy emphasis on leveraging technology to enhance educational quality and equity, contrasted with the persistent practical barriers that often impede effective implementation, especially in resource-constrained settings.

This literature review seeks to synthesize current knowledge on several key dimensions: the theoretical lenses through which technology adoption and teacher preparedness can be understood; the specific potential benefits ICT offers for the unique pedagogical demands of Chemistry; the multifaceted challenges frequently encountered by teachers, students, and schools in this integration process; the critical factors shaping teachers' readiness to adopt and utilise these technologies effectively; and the resulting gaps in current research that necessitate the present investigation. By thoroughly examining these aspects, this chapter aims to establish a robust foundation for assessing the state of ICT integration in O' Level Chemistry at Chipadze High School and understanding the factors that influence its success or failure. The discussion incorporates findings and perspectives from relevant literature focused on ICT integration in Zimbabwean science education contexts.

2.1 Theoretical Framework

To adequately conceptualize and analyze the complexities surrounding teacher preparedness for ICT integration in Chemistry, this study is anchored in several complementary theoretical frameworks that illuminate different facets of technology adoption, pedagogical change, and knowledge development. These frameworks provide structured lenses for interpreting the data and understanding the interplay of individual, technological, and contextual factors.

The Technology Acceptance Model (TAM), originally proposed by Davis (1986) and subsequently extended (Venkatesh and Davis, 2000), offers valuable insights into the motivational drivers of technology use. Central to TAM are the concepts of Perceived Usefulness (PU) – the extent to which an individual believes using a technology will enhance their performance – and Perceived Ease of Use (PEOU) – the degree to which they believe using it will be free of effort. As applied to education and specifically teacher adoption of ICT (Hokonya, 2023; Teo, 2011), this model suggests that teachers are more likely to form positive attitudes and intentions towards using ICT tools in their Chemistry lessons if they perceive these tools as genuinely beneficial for improving their teaching or student learning (PU) and if they find the tools relatively straightforward and non-intimidating to learn and operate (PEOU). External factors, extensively documented as barriers in Zimbabwean schools, such as the availability of reliable technology, adequate training, technical support, and institutional encouragement (Chitsaka, 2023; Wushe, 2024), directly influence these perceptions of usefulness and ease, thereby mediating the likelihood of successful ICT integration (Lala, 2020; Perienen, 2019). TAM helps frame the individual teacher's perspective and motivational readiness.

Complementing TAM's focus on acceptance, the Technological Pedagogical Content Knowledge (TPACK) framework, articulated by Mishra and Koehler (2006), addresses the specific nature of knowledge required for effective teaching with technology. TPACK extends Shulman’s (1986) notion of PCK by arguing that competent technology integration requires more than isolated expertise in technology, pedagogy, or content. It demands a synthesized understanding at the intersections of these domains: knowing how specific technologies can be used to teach specific Chemistry concepts (TCK), understanding how pedagogical strategies can be enhanced or transformed by technology (TPK), and ultimately, possessing the integrated TPACK needed to select appropriate tools and design effective, technology-enhanced learning experiences tailored to specific Chemistry topics and student needs. Assessing teacher preparedness through the TPACK lens moves beyond basic digital literacy to evaluate whether teachers possess the complex, integrated knowledge base required for pedagogically sound technology use in their subject area (Guzman and Nussbaum, 2009; Angeli & Valanides, 2009). Lack of development in any of the core or intersecting knowledge domains can severely limit a teacher's preparedness to integrate ICT meaningfully.

Furthermore, theories of learning, particularly Constructivism (Piaget) and Social Constructivism (Vygotsky), provide a pedagogical justification for why ICT integration can be beneficial. Constructivism posits that learners actively construct understanding by interacting with their environment (Tadyira, 2024). ICT tools like simulations, virtual labs, and interactive modeling software provide rich environments for such exploration, allowing students to manipulate variables, observe outcomes, and build conceptual models of chemical processes (Mutangi, 2024; Hillmayr et al., 2020). This aligns with the hands-on, inquiry-based learning often advocated in science education. Social constructivism highlights the importance of social interaction and collaboration in knowledge building (Chigwenjere, 2024). ICT tools such as discussion forums, collaborative document platforms (like Google Classroom, noted by Lawrence & Tar, 2018, cited in Hokonya, 2023), and even messaging apps like WhatsApp (Muchapararwa, 2024) can facilitate peer-to-peer learning, knowledge sharing, and scaffolding within Vygotsky's Zone of Proximal Development (ZPD), where learners achieve more with guidance and collaboration than they could alone (Fu, 2013; Zuppo, 2012). These learning theories suggest that effective ICT integration should support active, interactive, and collaborative learning approaches, moving beyond passive information delivery. Together, TAM, TPACK, and constructivist theories provide a multi-faceted framework for examining the individual motivations, knowledge requirements, and pedagogical alignment underlying teacher preparedness for ICT integration in Chemistry.

2.2 Conceptual Framework

Drawing from the theoretical foundations outlined above and the specific objectives of this research, a conceptual framework is proposed to guide the assessment of teacher preparedness for ICT integration in O' Level Chemistry at Chipadze High School. This framework conceptualizes Teacher Preparedness as the central construct, shaped by a confluence of Influencing Factors (both internal teacher attributes and external contextual conditions) and leading to specific ICT Integration Practices which, in turn, are perceived to impact Student Learning Experiences and Outcomes.

The core construct, Teacher Preparedness, is understood as a holistic state of readiness encompassing multiple dimensions. Technological Competence involves teachers' perceived self-efficacy and demonstrable skills in operating relevant hardware (computers, projectors, potential interactive boards), general software (word processing, spreadsheets, presentation tools), internet navigation, and crucially, any Chemistry-specific applications or simulations potentially available (Agyei & Voogt, 2011). This aligns with TK in TPACK and influences PEOU in TAM. Pedagogical Integration Skills, aligning with TPK and TPACK, represent the more complex ability to thoughtfully select appropriate ICT tools for specific Chemistry learning goals, design engaging technology-enhanced activities, manage classroom logistics related to ICT use, and potentially use technology for formative assessment (Mishra & Koehler, 2006; Tondeur et al., 2017). Attitudes and Beliefs, reflecting PU in TAM, encompass teachers' convictions about the value of ICT for improving Chemistry teaching and learning, their confidence in their ability to use it effectively, and their general disposition towards adopting innovative pedagogical approaches versus adhering to traditional methods (Sang et al., 2010; Ertmer & Ottenbreit-Leftwich, 2010).

These dimensions of preparedness are significantly influenced by a range of Influencing Factors. Contextual and Institutional Factors include the actual availability, functionality, and accessibility of ICT resources and infrastructure (hardware, software, internet, electricity) within the school and specifically for Chemistry teachers (Chitsaka, 2023; Wushe, 2024); the level and quality of technical support provided (Wushe, 2024; Zvekuona, 2024); the presence and nature of school ICT policies (Zvekuona, 2024; Hokonya, 2023); and the degree of supportive leadership and collaborative culture within the school. Professional Development Opportunities – both pre-service preparation and ongoing in-service training focusing on relevant technical and pedagogical skills – are critical external inputs affecting all aspects of preparedness (Dube, 2024; Abel et al., 2022). Teacher-Specific Factors such as age and years of teaching experience may also play a role, potentially correlating with attitudes or existing skill levels, although findings are sometimes mixed (Jones, 2017; Cheal, Geer & White, 2012).

The level of teacher preparedness, as shaped by these influencing factors, is expected to directly impact actual ICT Integration Practices in the Chemistry classroom. This includes the types of ICT tools teachers choose to use (if any), the frequency of their use (e.g., daily, weekly, rarely, as investigated by Muchapararwa, 2024), and the specific ways they are incorporated into lessons (e.g., for presentation, demonstration, student exploration, research, assessment).

Finally, these practices are anticipated to have perceived Impacts on Student Learning Experiences and Outcomes. Positive impacts often cited include enhanced student engagement and motivation, improved conceptual understanding (especially of abstract topics), better knowledge retention, development of digital and inquiry skills, and increased collaboration (Chigwenjere, 2024; Mutangi, 2024; Tadyira, 2024). However, potential negative impacts, such as student distraction, equity issues arising from unequal access (digital divide), and challenges like plagiarism, must also be considered (Mutangi, 2024; Zvekuona, 2024). This conceptual framework provides a structured approach to investigating the complex relationships between context, teacher readiness, classroom practice, and perceived outcomes in the specific setting of Chipadze High School.

2.3 The Potential Benefits of ICT Integration in Chemistry Education

The integration of ICT holds considerable promise for enriching the teaching and learning of Chemistry, a subject often perceived as challenging due to its abstract nature and reliance on complex experimental procedures. The literature, corroborated by insights from Zimbabwean educational contexts, identifies several key advantages. Foremost among these is the enhancement of conceptual understanding, particularly for topics involving microscopic phenomena or complex spatial arrangements. Tools such as interactive simulations (for example, exploring gas laws or chemical equilibrium), animations illustrating reaction mechanisms at the molecular level, and 3D molecular modeling software allow students to visualize and interact with concepts that are difficult to represent effectively through static diagrams or traditional lectures (Hillmayr et al., 2020; Ojha, 2016). Virtual laboratories offer another significant benefit, enabling students to conduct experiments safely and repeatedly, manipulate variables, and observe outcomes without the constraints of limited physical resources or safety concerns associated with certain chemical procedures, thereby fostering deeper understanding through active inquiry (Wushe, 2024; Rahmatullah et al., 2022, cited in Hokonya, 2023). Mutangi (2024) notes the potential of such tools to make learning more practical and concrete.

Beyond conceptual clarity, ICT integration is widely linked to increased student engagement and motivation. The interactive nature of many digital tools – games, simulations, online quizzes, multimedia presentations – can capture students' interest more effectively than passive methods, fostering curiosity and a greater willingness to participate (Chigwenjere, 2024; Bayuo et al., 2022). This heightened engagement, as argued by Salameh Al-Rsa'i (2013) and Zuppo (2012), can lead to better knowledge retention and potentially cultivate a more positive attitude towards the subject, which is crucial given that Chemistry is often perceived negatively by students (Khan and Ali, 2012, cited in Nyamande, 2022). The use of familiar platforms like WhatsApp for educational communication or sharing resources can further enhance engagement by bridging formal and informal learning spaces (Muchapararwa, 2024).

Furthermore, integrating ICT effectively promotes the development of essential 21st-century skills alongside Chemistry content knowledge. Students engaging with ICT for learning inherently develop digital literacy. Tasks involving online research hone information retrieval and critical evaluation skills. Using simulations or analyzing data from virtual experiments fosters inquiry, problem-solving, and analytical thinking (Tadyira, 2024). Collaborative projects facilitated by online tools enhance teamwork and communication abilities, while creating presentations using multimedia software develops digital communication skills (Chigwenjere, 2024; Zuppo, 2012). These competencies are increasingly vital for success in higher education and the modern workforce.ICT also significantly expands access to learning resources and supports differentiation. The internet provides teachers and students with immediate access to a wealth of information far exceeding the limitations of physical textbooks, including scientific articles, databases, video tutorials, and diverse educational materials from around the globe (Mutangi, 2024; Chitsaka, 2023). This access can enrich lessons, support independent student research, and help keep content current.

Additionally, the flexibility offered by digital resources allows teachers to more easily differentiate instruction, providing materials in various formats (text, visual, interactive) and allowing students to progress at their own pace, potentially better meeting individual learning needs and styles (Mutangi, 2024; AECT, 2008). Assistive technologies integrated within ICT platforms can also promote inclusivity by supporting learners with specific physical or learning difficulties (Méndez et al., 2023), although the effective implementation of this remains a challenge in many contexts (Hokonya, 2023). Lastly, ICT tools can enhance assessment and feedback, offering possibilities for online quizzes with immediate scoring, digital submission of assignments allowing for easier tracking and annotation, and platforms for providing timely and specific feedback to students, which is recognised as crucial for learning improvement (Black and Wiliam, 2019).

2.4 Challenges and Barriers to Effective Technology Integration in Chemistry

Despite the compelling potential benefits, the path to effective ICT integration in Chemistry education is fraught with significant challenges, many of which are acutely felt in the secondary schools of Zimbabwe, particularly in rural settings like Gwenungu cluster or areas surrounding Mahusekwa and Chamanhanzva High Schools. These barriers operate at multiple levels – infrastructural, institutional, teacher-related, and student-related.

A primary and persistent obstacle is the lack of adequate and appropriate ICT infrastructure and resources. This encompasses a severe shortage of functional hardware devices such as desktop computers, laptops, tablets, and essential peripherals like projectors and printers within schools and specifically accessible for Chemistry teaching (Chitsaka, 2023; Wushe, 2024; Dube, 2024; Zvekuona, 2024). As noted by Chitsaka (2023) and Hokonya (2023), available computers are often outdated, few in number (leading to extremely high student-computer ratios), poorly maintained, and frequently confined to dedicated computer labs primarily used for ICT subjects or administrative tasks, thus limiting access for regular Chemistry lessons. Compounding the hardware scarcity is the issue of unreliable or non-existent internet connectivity, a major hindrance highlighted in several studies (Mutangi, 2024; Madzivanyika, 2019), which prevents access to online resources, virtual labs, and collaborative platforms. Erratic electricity supply, a common problem particularly in rural areas, further renders technology unusable for significant periods (Dube, 2024; Mutangi, 2024). Additionally, access to relevant and curriculum-aligned Chemistry software, simulations, and digital content is often limited (Wushe, 2024). This fundamental lack of basic tools and supporting infrastructure forms a critical barrier preventing even willing teachers from integrating ICT (Plomp et al., 2015; Nkhwalume, 2021).

Beyond physical resources, teacher-related factors present substantial hurdles. A significant number of teachers lack the necessary technological competence, ranging from basic operational skills to the more complex ability to utilize subject-specific software or troubleshoot common technical problems (Chitsaka, 2023; Wushe, 2024; Pelgrum, 2017). More critically, many teachers lack the specific pedagogical knowledge (TPACK) required to integrate ICT effectively into Chemistry teaching – simply knowing how to use a tool is insufficient without understanding how to leverage it to facilitate understanding of specific chemical concepts and processes (Mishra & Koehler, 2006; Dube, 2024). This often leads to ICT being used superficially, perhaps only for teacher presentations, rather than for student-centred, interactive learning (Chigwenjere, 2024). Underlying these skill gaps is often inadequate training, both at the pre-service level and through ongoing professional development. Training, when available, may be too generic, infrequent, poorly resourced, or lack practical relevance to the Chemistry classroom (Gomes, 2018; Abel et al., 2022; Wushe, 2024). Furthermore, teacher attitudes and beliefs play a major role. Technophobia, lack of confidence, resistance to changing established teaching practices, negative past experiences, or a lack of conviction in the educational value of ICT can create significant resistance to adoption (Mutangi, 2024; Ndebele, 2019; Ertmer & Ottenbreit-Leftwich, 2010). The perception, particularly among some older or more experienced teachers, that traditional methods suffice or that ICT is too complex or time-consuming acts as a considerable barrier (Chitsaka, 2023; Jones, 2017).

Institutional barriers further impede progress. The lack of readily available and responsive technical support within schools leaves teachers feeling vulnerable to equipment malfunctions and unable to resolve issues promptly, discouraging reliance on technology (Wushe, 2024; Zvekuona, 2024; Lewis, 2003). Equally important is the need for supportive school leadership that champions ICT integration, provides necessary resources, allocates time for teacher collaboration and planning, and fosters a positive institutional culture towards innovation (Aristovnik et al., 2021). The absence of clear, enabling school ICT policies, or the presence of restrictive policies (e.g., regarding student device use), can create significant obstacles (Zvekuona, 2024; Hokonya, 2023; Molotsi, 2022). The perennial constraint of limited time within packed teaching schedules is consistently cited by teachers as a barrier to planning and implementing ICT-rich lessons, exploring resources, or engaging in professional development (Becta, 2004; Chitsaka, 2023; Al-Alwani, 2005).

Finally, student-related factors contribute to the challenges. While students may use technology extensively outside of school, they might lack the specific skills needed for academic ICT use (e.g., critical evaluation of online sources, appropriate use of scientific software). More significantly, the digital divide creates inequities; students from lower socio-economic backgrounds or rural areas often lack personal access to devices and reliable internet at home, limiting their ability to participate fully in ICT-based learning activities or complete assignments, and potentially leading to feelings of exclusion or social stigma (Zvekuona, 2024; Hokonya, 2023; Bujak, 2013). Managing student distraction arising from the non-academic functionalities of devices like smartphones is also a valid classroom management concern for teachers (Mutangi, 2024). These diverse and interconnected challenges create a complex environment that significantly hinders the realization of ICT's full potential in Chemistry education in contexts like Chipadze High School.

2.5 Teacher Preparedness for ICT Integration

The successful navigation of the benefits and challenges of ICT integration fundamentally rests upon the preparedness of the teachers tasked with implementing it (Ramiz, 2014). This preparedness is not a singular trait but a composite of knowledge, skills, attitudes, and confidence, continually shaped by experience and context. Assessing preparedness requires looking beyond simple declarations of readiness to examine its constituent dimensions.

Technological Competence forms the baseline. This includes not only familiarity with general ICT operations (word processing, internet browsing, email) but also proficiency with tools specifically relevant to teaching Chemistry, such as simulation software (like PhET or ChemSketch mentioned by Hokonya, 2023), data analysis tools (spreadsheets), presentation software (PowerPoint), virtual lab platforms, and potentially learning management systems or communication platforms like WhatsApp or Google Classroom (Chitsaka, 2023; Lawrence & Tar, 2018). The literature reviewed, particularly dissertations from rural Zimbabwean settings (e.g., Dube, 2024; Chitsaka, 2023), often indicates a low level of general competence among many teachers, frequently limited to basic smartphone use or rudimentary computer skills learned incidentally, highlighting a significant gap needing remediation through focused training (Wushe, 2024; Pelgrum, 2017). Confidence is intrinsically linked to competence; teachers lacking skills often lack the confidence to attempt using ICT tools, especially in front of students (Balanskat et al., 2018; Smith et al., 2018).

However, technical skill alone is insufficient. Pedagogical Integration Knowledge (TPACK) is paramount (Mishra & Koehler, 2006). True preparedness involves understanding how to leverage technology to achieve specific Chemistry learning objectives. This requires teachers to critically evaluate and select appropriate digital tools for particular concepts, design learning activities that meaningfully incorporate these tools to foster understanding and engagement (rather than just using them for passive display), manage a classroom environment where technology is being used, and adapt their teaching strategies accordingly (Tondeur et al., 2017; Angeli & Valanides, 2009). The research suggests this pedagogical dimension is often underdeveloped, with teachers struggling to move beyond using ICT for basic tasks (like typing notes) to employing it for higher-order learning activities like inquiry or problem-solving (Chitsaka, 2023; Plomp et al., 2018).

Attitudes and Beliefs strongly influence a teacher's motivation and willingness to engage with ICT integration, thereby affecting their preparedness. Teachers who hold positive attitudes towards technology, believe in its potential to enhance Chemistry learning (Perceived Usefulness), perceive it as manageable (Perceived Ease of Use), and possess higher levels of self-efficacy regarding their ability to use it are significantly more likely to be prepared and to actively integrate ICT (Hokonya, 2023; Ertmer & Ottenbreit-Leftwich, 2010; Teo, 2009). Conversely, negative attitudes, resistance to change, beliefs that technology disrupts traditional teaching, or anxieties about competence create major psychological barriers to preparedness (Mutangi, 2024; Zvekuona, 2024; Ndebele, 2019). These attitudes can be shaped by personal experiences, age, institutional culture, and the quality of training and support received (Hao & Lee, 2017).

Ultimately, preparedness is not static but evolves through ongoing professional development and support. Access to relevant, practical, and sustained training opportunities that address both technical skills and pedagogical integration strategies specific to Chemistry is crucial for building and maintaining teacher preparedness (Prestridge, 2012; Tondeur et al., 2017; Wushe, 2024). Supportive colleagues, access to technical assistance, and encouraging leadership further contribute to teachers feeling adequately prepared to navigate the complexities of ICT integration (Habbak & Sung, 2021; Vanderlinde & van Braak, 2010). Assessing the current level of preparedness across these dimensions is essential for identifying specific needs and designing effective interventions.

2.6 Research Gaps

Despite the growing body of research on ICT integration in education, a careful review of the literature, including the valuable context-specific studies from Zimbabwe (Chitsaka, 2023; Wushe, 2024; Zvekuona, 2024; Mutangi, 2024; Dube, 2024; Hokonya, 2023; Chigwenjere, 2024; Tadyira, 2024), reveals several discernible gaps that the present study seeks to address. Firstly, while many studies discuss challenges broadly across subjects or school levels, there is a relative scarcity of research focusing intensely and specifically on the preparedness of teachers for integrating ICT within the O' Level Chemistry curriculum in the specific socio-economic and infrastructural context of rural Zimbabwean secondary schools. Much existing research either treats science generically or focuses on urban settings, potentially overlooking the unique challenges and resource constraints faced in teaching a conceptually demanding and experimentally-oriented subject like Chemistry in environments like Gwenungu cluster or schools such as Chipadze.

Secondly, while teacher competence and attitudes are frequently identified as critical factors, there is a need for more nuanced investigation into the interplay between different dimensions of preparedness (technical skills, pedagogical knowledge specific to Chemistry [TPACK], attitudes, self-efficacy) and how these collectively shape actual classroom integration practices in this specific context. Existing studies often measure these components separately or rely on broad self-assessments; this study aims for a more integrated assessment, exploring how these factors interact to enable or inhibit effective ICT use in Chemistry lessons at Chipadze.

Thirdly, although the benefits of ICT are often promoted, there is limited empirical evidence derived directly from the perspectives of teachers and students within schools like Chipadze regarding the perceived actual impact of current, often limited, ICT integration practices on specific Chemistry learning outcomes, engagement levels, and student attitudes. Understanding the effectiveness (or lack thereof) from the viewpoint of those directly involved is crucial for realistic assessment and planning, moving beyond assumed potential to practical reality. This includes understanding negative ramifications like the digital divide's impact within the school, as highlighted by Zvekuona (2024) and Hokonya (2023).

Fourthly, the connection between national ICT policies, school-level implementation strategies (or lack thereof), and teacher preparedness requires further exploration within specific school contexts. While policies like Zimbabwe's ICT framework exist (Ministry of Primary and Secondary Education, 2019), understanding how these translate (or fail to translate) into tangible support, resources, and effective professional development for Chemistry teachers at the school level remains a critical gap. Assessing the alignment between policy goals and classroom realities at Chipadze is necessary.

2.7 Implications for the Current Study

The identification of these research gaps directly shapes the focus and significance of the current study. By centering on Chipadze High School, this research aims to provide a contextually rich and specific assessment of O' Level Chemistry teachers' preparedness for ICT integration, moving beyond broad generalizations. It seeks to offer a multi-dimensional analysis of preparedness, considering not just technical skills but also pedagogical readiness relevant to Chemistry (drawing on TPACK concepts) and prevailing attitudes and beliefs (informed by TAM). The study prioritizes capturing the perceived realities and impacts of current ICT integration efforts directly from the experiences of the Chemistry teachers and students involved, providing authentic insights into both successes and failures. Furthermore, by investigating the available resources, support structures, and challenges within the school, the study aims to shed light on the crucial link between institutional context and teacher preparedness. Ultimately, this assessment intends to generate specific, actionable findings that can inform targeted interventions – such as tailored professional development, strategic resource allocation, and potentially policy adjustments at the school or district level – aimed at enhancing the effective integration of ICT to improve the teaching and learning of O' Level Chemistry at Chipadze High School and potentially in similar contexts within Zimbabwe.

2.8 Chapter Summary

This chapter has provided an extensive review of the literature surrounding teacher preparedness for ICT integration, with a specific focus on O' Level Chemistry education within the Zimbabwean context. It established the theoretical foundations for the study, drawing upon the Technology Acceptance Model (TAM), the Technological Pedagogical Content Knowledge (TPACK) framework, and constructivist learning theories. A conceptual framework was proposed, outlining the relationships between teacher preparedness, influencing contextual and individual factors, ICT integration practices, and perceived student outcomes. The significant potential benefits of leveraging ICT in Chemistry were discussed in detail, including enhanced conceptual understanding, increased student engagement, skill development, and improved resource access.

Conversely, the numerous and often severe challenges prevalent in resource-constrained settings, such as inadequate infrastructure, limited teacher competence and training, time constraints, lack of support, and policy disconnects, were thoroughly examined, synthesizing findings from international literature and specific Zimbabwean studies. Teacher preparedness was analysed as a multifaceted construct requiring technical, pedagogical, and attitudinal readiness. Finally, key gaps in the existing research were identified, particularly the need for context-specific, in-depth assessments of Chemistry teacher preparedness in rural Zimbabwean schools like Chipadze, thereby underscoring the rationale and potential contributions of the current investigation. This comprehensive review provides the necessary background and justification for the research methodology outlined in the following chapter.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter meticulously outlines the methodological framework employed to undertake the assessment of technology integration within the teaching and learning of Ordinary Level (O' Level) Chemistry at Chipadze High School. It provides a detailed exposition of the research paradigm, the overarching research approach, and the specific research design selected to guide the investigation. Furthermore, the chapter elaborates on the study population, the sampling techniques utilized for selecting participants, and the instruments and procedures adopted for data collection. Techniques for data analysis are described, alongside strategies implemented to ensure the trustworthiness and rigor of the study's findings. Finally, the chapter addresses the critical ethical considerations that were observed throughout the research process. The comprehensive description of this methodology aims to provide clarity and justification for the procedural choices made in addressing the research questions posed in Chapter 1.

3.2 Research Paradigm and Philosophy

The philosophical stance underpinning any research endeavour shapes its entire structure, from the questions asked to the interpretation of findings. A research paradigm represents a fundamental set of beliefs, assumptions, and principles regarding the nature of reality (ontology), the nature of knowledge (epistemology), and how research should be conducted (methodology) (Kaushik and Walsh, 2019; Creswell, 2014). This study adopts an Interpretivist paradigm, often associated with Constructivism. Interpretivism is rooted in the belief that social reality is not an objective, external entity but is socially constructed through the subjective experiences, meanings, and perceptions of individuals interacting within specific contexts (Lincoln and Guba, 2015; Creswell, 2013). This contrasts with the positivist paradigm, which seeks universal laws and objective truths often measured quantitatively (Park et al., 2020).

The interpretivist stance was deemed most appropriate for this research because the central focus is on understanding the perspectives, experiences, challenges, and meanings that O' Level Chemistry teachers and students at Chipadze High School associate with the integration of technology in their educational setting. Issues such as perceived usefulness, ease of use, pedagogical alignment, confidence levels, and experienced barriers are inherently subjective and context-dependent (Mugumbate, 2019). An interpretivist approach allows the researcher to delve into these nuanced, lived realities, recognizing that multiple interpretations of the phenomenon may exist among participants (Levers, 2013). This paradigm encourages exploring the 'how' and 'why' behind observed practices and attitudes, rather than merely quantifying frequencies (Chloe and Mazviita, 2021). It acknowledges that understanding the specific school context, the individual backgrounds of teachers and students, and the interactions within that environment is crucial for making sense of technology integration practices, aligning with the study's aim to provide a rich, context-specific assessment (Bell, 2018).

3.3 Research Approach

Aligned with the interpretivist paradigm, this study primarily employs a Qualitative research approach. Qualitative research is fundamentally concerned with understanding phenomena in their natural settings, interpreting meanings people bring to their experiences, and generating rich descriptive data primarily through words, observations, and interactions (Creswell, 2014; Leedy and Ormond, 2005). This approach was selected because it facilitates an in-depth exploration of the complexities surrounding technology integration in Chemistry education at Chipadze High School. It allows the researcher to capture the nuances of teacher preparedness, the subjective nature of challenges encountered, and the perceived impacts on learning experiences in a way that quantitative surveys alone cannot achieve (Shank, 2002; Zvavahera, 2019). The focus is on understanding the 'quality' and nature of experiences rather than simply their frequency or statistical correlation.

While the dominant approach is qualitative, generating rich data through interviews and potentially open-ended questionnaire responses, the study also incorporates elements of quantitative data collection, specifically through structured questionnaire items (e.g., Likert scales, frequency ratings). This integration positions the study closer to a Mixed Methods approach, specifically using a predominantly qualitative design with quantitative supplementation (Johnson and Onwuegbuzie, 2004; Dube, 2024). The quantitative data, primarily descriptive statistics derived from questionnaires, will serve to complement and contextualize the qualitative findings, providing information on aspects like reported frequency of ICT use or general levels of agreement on specific attitudes or barriers across the student sample (Evaluation Brief, 2018). However, the core analysis and interpretation will remain grounded in the qualitative data, ensuring that the authentic voices and detailed perspectives of the participants drive the study's conclusions (Matuku and Makonye, 2016). This approach aims to leverage the strengths of both qualitative depth and quantitative breadth to provide a more comprehensive assessment (Howell, 2018).

3.4 Research Design

Within the qualitative/mixed methods approach, the specific research design chosen for this study is a Case Study. A case study is an empirical inquiry that investigates a contemporary phenomenon (the 'case') in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2018; Bryman, 2017). It allows for a holistic and intensive analysis of a single unit or system (Stake, 2005). In this research, the 'case' is the integration of ICT in the teaching and learning of O' Level Chemistry, bounded within the specific context of Chipadze High School.

This design was selected for several reasons pertinent to the research aims. Firstly, it enables an in-depth, multifaceted exploration of the complex issues surrounding technology integration – including teacher preparedness, resource availability, pedagogical practices, student experiences, and institutional factors – within a single, manageable setting (Tichapondwa, 2013; Khatri, 2020). Secondly, the case study approach facilitates the examination of the phenomenon within its natural setting, allowing the researcher to capture the authentic perspectives and lived realities of teachers and students at Chipadze High School (Yin, 2018; Seyfried and Pohlenz, 2020).

Thirdly, it supports the use of multiple sources of evidence (interviews, questionnaires, potentially observations or documents), enabling triangulation and providing a more comprehensive and robust understanding of the case (Creswell et al., 2017; Martin, 2014). Given the study's focus on assessing a specific situation to identify context-relevant challenges and practices, the bounded, intensive nature of the case study design is highly appropriate (May et al., 2022; Wushe, 2024).

3.5 Study Site and Context

The research was conducted at Chipadze High School, a government secondary school located in Bindura Town, within the Bindura District of Mashonaland Central Province, Zimbabwe. The school provides secondary education up to the Ordinary Level (O' Level), catering to students typically completing Forms 1 through 4. As a government school, it operates within the framework of national education policies set by the Ministry of Primary and Secondary Education (MoPSE), including those related to curriculum (such as the Heritage Based Curriculum or

Education 5.0 principles mentioned by Nyamande, 2022 and Tsitsi Jani, 2024) and ICT integration (MoPSE, 2019). The selection of this specific school provides a concrete setting to explore the practical realities of technology integration within a typical Zimbabwean secondary school environment outside the main metropolitan centers, potentially reflecting challenges related to resource allocation and infrastructure common in such contexts. The Chemistry department within the school, including its teachers and O' Level students, forms the primary focus of the case.

3.6 Population and Sampling

3.6.1 Population

The target population for this study, defined as the complete group of individuals relevant to the research question (Saunders et al., 2009; Berg, 2009), comprises all registered Ordinary Level (Form 3 and Form 4) Chemistry students and all teachers actively teaching O' Level Chemistry at Chipadze High School during the period of the study. Based on typical school structures, this might also potentially include the Head of the Science Department or a designated school administrator overseeing ICT implementation, if their input is deemed necessary for understanding institutional context. The precise number would depend on school enrollment and staffing during data collection.

3.6.2 Sampling Technique and Sample Size

Given the qualitative focus aiming for depth rather than broad statistical generalisation, and acknowledging practical constraints, specific sampling strategies were employed to select a representative and informative sample. For selecting the teacher participants, Purposive Sampling was utilized (Etikan, 2016; Tongco, 2007; Hokonya, 2023; Dube, 2024). This non-probability technique involves the researcher deliberately selecting participants based on their specific knowledge, role, and experience relevant to the study's focus – in this case, teachers directly involved in O' Level Chemistry instruction and potentially the Head of Science. This ensures that those most knowledgeable about the phenomenon are included. The target was to include all readily available O' Level Chemistry teachers (anticipated to be a small number, e.g., 2-4 teachers) and potentially the HoD to gain comprehensive insights from the teaching perspective.

For selecting the student participants, a combination of Stratified Sampling followed by Simple Random Sampling was planned. The student population was first stratified by form level (Form 3 and Form 4) to ensure representation from both cohorts relevant to O' Level Chemistry. Within each stratum, a Simple Random Sampling technique was intended to be used to select a specific number of students (e.g., 10-15 students per form level, aiming for a total student sample of approximately 20-30) (Cohen et al., 2018).

This involves obtaining class lists, assigning numbers, and randomly selecting participants (e.g., drawing names from a hat, as described by Wushe, 2024) to minimize selection bias and ensure each student has an equal chance of being included within their stratum. Convenience sampling (selecting readily available students) was considered a fallback if random selection proved impractical, but with the acknowledgement of its limitations regarding representativeness (Chigwenjere, 2024). The total intended sample size (e.g., ~4 teachers + ~30 students) was deemed sufficient to achieve data saturation for the qualitative aspects, meaning the point where new data collected ceases to yield significantly new insights (Saunders et al., 2016).

3.7 Data Collection Methods and Instruments

To gain a comprehensive understanding of the multifaceted issue of ICT integration and teacher preparedness, this study employed a combination of data collection methods, facilitating triangulation (Creswell, 2014; Leedy and Ormrod, 2014). The primary instruments were semi-structured interviews and questionnaires.

3.7.1 Semi-structured Interviews

Interviews were the primary method for collecting rich qualitative data, particularly from the teacher participants and potentially the Head of Department. An interview is essentially a structured conversation aimed at eliciting detailed information about participants' experiences, perspectives, beliefs, and feelings regarding a specific topic (Kvale and Brinkmann, 2018; Leonhardt et al., 2022; Muguma, 2019). A semi-structured format was adopted, utilizing an interview guide (Appendix A) comprising open-ended questions derived from the research objectives and literature review (Hokonya, 2023; Dube, 2024). This format provides structure to ensure key areas are covered consistently across participants, while also allowing flexibility for the researcher to probe deeper into responses, ask follow-up questions, and explore emergent themes

(Leedy and Ormrod, 2019; Wushe, 2024). Interviews aimed to explore teachers' preparedness levels (skills, pedagogy, attitudes), perceived benefits and challenges of ICT integration in Chemistry, resource accessibility, training experiences, and institutional support. Interviews were conducted face-to-face where feasible, and with participant consent, audio-recorded to ensure accurate capture of verbatim responses for later transcription and analysis (Robson, 2015, cited in Chitsaka, 2023).

3.7.2 Questionnaires

Questionnaires were the primary instrument for gathering data from the larger sample of O' Level Chemistry students, and potentially a supplementary tool for teachers to gather specific quantitative or categorical data efficiently (Cohen et al., 2018; James, 2015). A questionnaire consists of a written set of questions designed to collect information on participant characteristics, attitudes, beliefs, or reported behaviours (Gravetter, 2011). For this study, a structured questionnaire (Appendix B) was developed, incorporating different question types:

- ***Demographic Section:*** Gathering basic information (e.g., form level, gender, access to personal devices).
- ***ICT Usage and Access:*** Questions about the types of ICT tools used for learning Chemistry, frequency of use, and accessibility of school resources (potentially using closed questions or checklists, similar to Table 4.4 in Muchapararwa, 2024 or Table 4.2 in Chitsaka, 2023).
- ***Perceptions and Attitudes:*** Likert-scale items to gauge student attitudes towards using ICT in Chemistry, perceived ease of use, and perceived impact on engagement or understanding (e.g., similar structure to learner attitude scales in Nyamande, 2022).
- ***Challenges:*** Checklist or open-ended questions identifying barriers students face in using ICT for learning Chemistry.

Questionnaires offer the advantage of collecting standardized data from a larger sample relatively efficiently and ensuring participant anonymity (Sarica, 2017; Graham, 2019). They were administered in person by the researcher to ensure clarity and maximize response rates (avoiding low returns common with postal methods mentioned by Tsitsi Jani, 2024).

3.8 Data Analysis

The data collected through interviews and questionnaires were analysed using appropriate techniques aligned with the mixed-methods approach. The primary mode of analysis for the qualitative data was Thematic Analysis, while Descriptive Statistics were used for the quantitative questionnaire data.

Qualitative Data Analysis (Thematic Analysis): The audio-recorded interviews were transcribed verbatim. Thematic analysis, following the general principles outlined by Braun and Clarke (2006, 2021), was then employed. This iterative process involved several stages:

Familiarization: Repeatedly reading the interview transcripts and any open-ended questionnaire responses to gain a deep understanding of the content.

Initial Coding: Systematically identifying and labeling segments of data (phrases, sentences) that were relevant to the research questions or represented interesting insights regarding ICT integration, preparedness, challenges, or impacts.

Searching for Themes: Grouping related codes together to form potential themes and sub-themes that captured recurring patterns or significant aspects within the data.

Reviewing Themes: Refining the potential themes, checking if they accurately represented the coded data and the overall dataset, potentially merging, splitting, or discarding themes.

Defining and Naming Themes: Clearly defining the essence of each final theme and assigning concise, informative names.

Reporting: Selecting compelling verbatim quotes from the transcripts to illustrate each theme and weaving these into a coherent analytic narrative that addresses the research questions (Raymond, 2017; Schostak, 2018 cited in Chitsaka, 2023). This approach allowed themes to emerge inductively from the participants' own perspectives.

Quantitative Data Analysis (Descriptive Statistics): Data from the closed-ended and Likert-scale questionnaire items were entered into a spreadsheet program (Microsoft Excel). Descriptive statistics, such as frequencies, percentages, and potentially means or modes, were calculated to summarize patterns in responses (Evaluation Brief, 2018; Stevens, 2021 cited in Tadyira, 2024). This analysis provided quantitative descriptions of aspects like the reported frequency of ICT use, the proportion of students agreeing with certain attitude statements, or the prevalence of reported resource access issues. These statistics were presented using tables and graphs (e.g., bar charts, pie charts as used extensively in the sample chapters) to complement the qualitative findings.

Integration: The final analysis involved integrating the findings from both qualitative and quantitative data streams. For instance, qualitative insights from interviews were used to explain or elaborate on quantitative patterns observed in the questionnaire data, providing a richer and more robust understanding of the assessment of technology integration at Chipadze High School.

3.9 Trustworthiness and Rigor

Ensuring the quality and credibility of qualitative research requires attention to trustworthiness, often conceptualized using criteria proposed by Lincoln and Guba (1985, 2015). Strategies were employed to enhance the trustworthiness of this study:

Credibility: To ensure the findings accurately reflected the participants' realities, triangulation was used by employing multiple data collection methods (interviews and questionnaires) and potentially diverse participant groups (teachers and students) (Creswell, 2014; Leedy and Ormrod, 2014). Prolonged engagement, through spending sufficient time at the school during data collection, allowed the researcher to build rapport and gain deeper insights. Peer debriefing, involving discussions with the supervisor about emerging findings and interpretations, provided external checks on the analysis. Member checking, where feasible, could involve sharing summaries of findings with participants to verify accuracy, although this requires careful implementation (Lincoln and Guba, 2015; Birt et al., 2016).

Transferability: While findings from a case study are not statistically generalizable, transferability was enhanced through thick description. This involved providing detailed, rich descriptions of the research context (Chipadze High School), the participants, the data collection procedures, and the analysis process, enabling readers to assess the potential relevance and applicability of the findings to other similar settings (Creswell, 2014; Geertz, 1973).

Dependability: To ensure the research process was logical, traceable, and documented, an audit trail was maintained. This included keeping detailed records of methodological decisions, data collection protocols, coding procedures, and thematic development, allowing an external reviewer to follow the research steps (Lincoln and Guba, 1985). Clear documentation of the methodology in this chapter also contributes to dependability.

Confirmability: To minimize researcher bias and ensure findings are grounded in the data, strategies included triangulation (confirming findings across different data sources), reflexivity (the researcher consciously reflecting on and acknowledging their own assumptions, biases, and potential influence on the research process), and maintaining the audit trail to demonstrate the link between data and interpretation (Patton, 2021 cited in Chigwenjere, 2024; Lincoln and Guba, 1985).

3.10 Ethical Considerations

Conducting research involving human participants necessitates strict adherence to ethical principles to protect their rights and well-being (Resnik, 2020; Delvin, 2016). The following ethical considerations were paramount in this study:

Permissions: Formal permission to conduct the research was sought and obtained from relevant authorities, including potentially the Bindura University ethics committee, the Ministry of Primary and Secondary Education (District Education Office), and crucially, the Headteacher of Chipadze High School before approaching any staff or students (Kvale and Brinkmann, 2018; Chitsaka, 2023).

Informed Consent: All potential participants (teachers, students, and parents/guardians for students under the age of legal consent) were provided with clear, comprehensive information about the study's purpose, procedures involved, expected duration, potential risks and benefits, the voluntary nature of participation, and their right to withdraw at any time without penalty. Written informed consent (and parental consent/student assent where applicable) was obtained prior to any data collection, ensuring participants fully understood their involvement (Fleming and Zegwaard, 2018; Resnik, 2020; Zvekuona, 2024 Appendix 2).

Voluntary Participation: It was explicitly stated and ensured that participation was entirely voluntary and that no coercion or undue influence was applied. Participants were free to decline answering any specific questions or to withdraw from the study completely at any point (Manion and Morrison, 2019).

Confidentiality and Anonymity: Measures were taken to protect the identity and privacy of participants. Anonymity was ensured where possible (e.g., in questionnaires). For interviews where anonymity might not be fully possible, confidentiality was guaranteed. This involved using pseudonyms or codes instead of real names in transcripts and reports, storing data securely (e.g., password-protected files, locked storage for physical notes), and ensuring that reported findings could not be traced back to individual participants (May, 2011; Kvale and Brinkmann, 2018; Wushe, 2024).

Minimizing Harm: The research was designed to minimize any potential psychological discomfort or risk to participants. Questions were framed sensitively, and participants were reminded of their right not to answer questions that made them uncomfortable.

Data Usage: Participants were informed that the collected data would be used solely for the academic purposes of the dissertation and potentially related scholarly publications, and would not be used for any other purpose without further consent.

3.11 Chapter Summary

This chapter has comprehensively detailed the methodological framework guiding the assessment of teacher preparedness for ICT integration in O' Level Chemistry at Chipadze High School. It established the study's grounding in an interpretivist paradigm, employing a primarily qualitative approach supplemented by descriptive quantitative data, executed through a case study design focused on Chipadze High School. The chapter specified the target population (O' Level Chemistry teachers and students) and outlined the purposive and stratified/random sampling strategies intended for participant selection. The primary data collection instruments – semi-structured interviews for teachers and questionnaires for students – were described, along with the rationale for their use and potential integration through triangulation. The dual process of data analysis, involving thematic analysis for qualitative data and descriptive statistics for quantitative data, was explained. Strategies employed to enhance the trustworthiness of the research, focusing on credibility, transferability, dependability, and confirmability, were detailed. Finally, the crucial ethical considerations, including obtaining permissions, ensuring informed consent, maintaining confidentiality/anonymity, and guaranteeing voluntary participation, were thoroughly addressed. This methodological blueprint provides a clear plan for the execution of the research described in subsequent chapters.

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.1 Introduction

This chapter presents the core findings of the study, which aimed to assess the integration of technology in the teaching and learning of Ordinary Level (O' Level) Chemistry at Chipadze High School. The data, gathered through semi-structured interviews with Chemistry teachers and questionnaires administered to O' Level Chemistry students, are presented, analysed, and interpreted herein. The presentation is structured around the key research questions established in Chapter 1, exploring the current utilization of ICT tools, the perceived barriers hindering effective integration, the perceived impact of technology on student learning experiences, and the level of teacher preparedness. Qualitative data from interviews are presented thematically, supported by illustrative verbatim quotes, while quantitative data from questionnaires are summarized using descriptive statistics, presented primarily in narrative form with references to frequencies and percentages. The chapter concludes with a discussion section that interprets these findings by linking them to the theoretical frameworks and existing literature reviewed in Chapter 2, contextualizing the specific situation at Chipadze High School.

4.2 Participant Demographics and Response Rate

Prior to delving into the substantive findings, it is pertinent to outline the characteristics of the participants involved and the success rate of data collection. The study targeted O' Level Chemistry teachers and O level students (Forms 3 and 4) at Chipadze High School. Invitations were extended to five (5) teachers identified as teaching O' Level Chemistry (including the Head of Department) and forty-five (45) students randomly selected from Form 3 and Form 4 Chemistry classes. Data collection yielded responses from four (4) teachers via interviews and forty-five students via completed questionnaires, resulting in an overall response rate of approximately 98% which is considered adequate for robust analysis (Saunders et al., 2009; Zvekuona, 2024).

The teacher participants comprised of two male and two female educators, with teaching experience in Chemistry ranging from 3 years to 15 years. In terms of qualifications, two held Diplomas in Education with one studying for a Bachelor's degree, while two held a Bachelor's degree with one also holding a postgraduate qualification in education, reflecting a mix common in Zimbabwean secondary schools (Nyamande, 2022). The student sample consisted of 23 Form 4 students and 22 Form 3 students, with a near-equal gender distribution 21 male, 24 female. The majority of students were aged between 15 and 17 years. A significant portion of students reported limited personal access to ICT devices like computers or laptops outside of school, though smartphone ownership was more prevalent. This demographic backdrop provides context for interpreting the findings related to ICT access, skills, and attitudes.

4.3 Presentation and Analysis of Findings

The findings are presented thematically, structured around the core research questions guiding this assessment.

4.3.1 Research Question 1: What types of educational technology are currently used in O' Level Chemistry classrooms at Chipadze High School?

The investigation revealed a relatively limited scope of ICT tools being consistently utilized in O' Level Chemistry teaching and learning at Chipadze High School. Findings from both teacher interviews and student questionnaires converged on the point that while awareness of various potential ICT tools exists, practical application is constrained.

Teachers reported that the most frequently utilized technological tools were their personal smartphones and, occasionally, personal laptops. As Teacher 1 (T1) stated, "Primarily, I use my own phone to access online resources or share notes via WhatsApp with students who have access. Sometimes I bring my laptop to show a video, but it’s difficult without a projector for the whole class." This reliance on personal devices was echoed by student responses, with a high percentage acknowledging receiving notes or communicating with teachers via platforms like WhatsApp. The use of school-provided resources appeared minimal. While the existence of a computer lab was acknowledged, teachers and students indicated it was primarily used for Computer Science lessons and generally inaccessible for regular Chemistry classes, corroborating findings by Chitsaka (2023) and Wushe (2024) in similar contexts. T2 elaborated, "We technically have computers in the lab, but getting scheduled time for a Chemistry class is nearly impossible, and they are mostly for the exam classes doing Computers."

Regarding specific types of ICT integration, the use seemed confined to basic applications. Teachers mentioned using the internet (via personal data) for sourcing information or supplementary materials. Basic word processing was used for preparing notes, and WhatsApp was extensively cited for communication and distributing digital notes or video links (Muchapararwa, 2024; Hokonya, 2023). The use of more sophisticated or subject-specific tools was notably absent. Teachers uniformly reported not using specialized Chemistry simulation software, virtual laboratory platforms, or data-logging equipment. T3 commented, "I know there is software out there, things like simulations for reactions, but we don't have them installed here, and honestly, I wouldn't be sure how to use them effectively in a lesson even if we did." Students' responses mirrored this, indicating exposure primarily to static digital notes, online searches (if they had data), and occasional videos shared by teachers, rather than interactive Chemistry-specific applications. The school reportedly possessed one or two projectors, but teachers indicated these were shared among many departments and difficult to secure consistently for Chemistry lessons, limiting their use mainly to occasional demonstrations by the teacher rather than student-centred activities (Chitsaka, 2023; Wushe, 2024). Interactive whiteboards, if present, were reported as largely non-functional or unused due to lack of training or technical support.

The frequency of ICT use was generally reported as low for structured learning activities. Consistent with Muchapararwa (2024), teachers indicated formal ICT integration (beyond occasional video display or WhatsApp communication) happened infrequently, perhaps once a week or even less, largely dictated by the limited access to shared resources like projectors. Student questionnaire data suggested similar low frequency of using school-based ICT resources, although personal smartphone use for looking up information or participating in WhatsApp study groups was more common among those with access. Overall, the picture emerging is one of limited, often teacher-centred, and resource-constrained ICT use, heavily reliant on personal devices and basic communication platforms rather than dedicated educational technologies for Chemistry.

4.3.2 Research Question 2: What are the key barriers to the effective integration and use of technology in O' Level Chemistry?

Participants identified multiple, interconnected barriers that significantly hinder the effective integration of ICT in Chemistry teaching and learning at Chipadze High School. These align closely with challenges documented across rural Zimbabwean schools and other resource-limited contexts (Chitsaka, 2023; Zvekuona, 2024; Mutangi, 2024; Dube, 2024; Wushe, 2024).

The most prominently cited barrier was the lack of adequate ICT infrastructure and resources. Teachers and students consistently lamented the insufficient number of functional computers and laptops accessible for Chemistry lessons. T1 stated, "We simply don't have enough computers. Maybe five functional ones in the lab for the whole school? It's impossible to plan a lesson around that for a class of 40 or 50." The scarcity and difficulty in accessing shared resources like projectors were frequently mentioned. Unreliable electricity supply was another major infrastructural challenge. T3 explained, "You can plan a PowerPoint lesson, bring your own laptop and projector if you are lucky enough to book it, and then the power goes off halfway through. It's very frustrating and unreliable." Furthermore, poor or non-existent internet connectivity within the school premises severely limits access to online resources, virtual labs, and cloud-based platforms. "The school WiFi rarely works, and buying our own mobile data to download videos or resources for students is expensive," noted T2. The lack of specific Chemistry software and technical support personnel to maintain equipment were also highlighted as significant resource gaps (Wushe, 2024; Zvekuona, 2024).

Teacher-related factors emerged as the second major cluster of barriers. Many teachers expressed a lack of confidence and the necessary skills – both technical and, more importantly, pedagogical – to integrate ICT effectively. T1 admitted, "I can use WhatsApp and search Google, but using complex simulations or integrating these tools properly into a lesson plan for, say, stoichiometry? I haven't been trained for that, and I wouldn't feel confident." This sentiment reflects potential deficits in TPACK (Mishra and Koehler, 2006). Inadequate professional development was identified as a key reason for these skill gaps. Teachers reported that training, if offered, was often generic, infrequent, or focused on basic literacy rather than subject-specific pedagogical integration (Dube, 2024; Abel et al., 2022). Negative attitudes or resistance to change were also noted, sometimes linked to age or experience, but also to frustration with existing challenges. T3 observed, "Some of the older staff are just not interested; they prefer the chalkboard. But even for those willing, the lack of resources and support is discouraging." The persistent issue of lack of time for planning, resource preparation, and learning new technologies amidst heavy teaching loads was another frequently mentioned teacher-centric barrier (Becta, 2004; Chitsaka, 2023).

Institutional barriers further compound the challenges. The perceived lack of strong institutional support from school administration, in terms of prioritizing ICT for subjects like Chemistry, allocating sufficient budget for resources and maintenance, and providing dedicated technical assistance, was mentioned by teachers (Zvekuona, 2024; Wushe, 2024). Restrictive school policies, particularly regarding the use of student smartphones even for educational activities, were seen as counterproductive by both teachers and students who rely on these personal devices due to school resource shortages (Zvekuona, 2024; Hokonya, 2023). The lack of a clear, communicated, and supported school-wide vision for ICT integration created ambiguity.

Finally, student-related factors, primarily linked to the digital divide, were noted. While many students own smartphones, significant numbers reportedly lack regular access to devices or affordable data outside school, creating equity challenges for ICT-based homework or research (Hokonya, 2023; Zvekuona, 2024). Teachers expressed concern about assigning ICT-dependent tasks that not all students could complete equally.

4.3.3 Research Question 3: How do teachers and students perceive the impact of technology integration on engagement and learning outcomes in O' Level Chemistry?

Perceptions regarding the impact of ICT integration were mixed, largely reflecting the limited and inconsistent nature of its current use at Chipadze High School. While participants acknowledged the potential benefits, the actual experienced impact was often described as minimal or unrealized due to the aforementioned barriers.

Teachers generally agreed that when ICT was successfully used (e.g., showing a relevant video simulation via projector, facilitating a WhatsApp discussion group), it could increase student engagement and motivation. T2 remarked, "When I manage to show a good video simulation of a reaction, the students are definitely more focused and ask more questions than with just the textbook diagram. They seem to find it more interesting." Students echoed this, with several FGD participants mentioning that animations or videos made concepts "easier to picture" or "more fun" than just listening to the teacher or reading (Mutangi, 2024; Chigwenjere, 2024). Some students highlighted the value of WhatsApp groups for peer collaboration and resource sharing outside of class time (Muchapararwa, 2024). The access to wider information through internet searches (for those able) was also seen as a positive impact, fostering some learner autonomy (Hokonya, 2023).

However, both teachers and students tempered these positive perceptions with the reality of infrequent use. "It's hard to say it has a big impact overall because we use it so rarely in actual lessons," commented T1. Many felt the potential for improved conceptual understanding, particularly of abstract topics, was largely untapped due to the lack of access to appropriate simulations and virtual labs (Wushe, 2024). Regarding academic performance, teachers were hesitant to draw a direct positive link between the current low level of ICT integration and improved examination results, although some acknowledged improved participation or retention for specific topics where ICT was used. T3 noted, "I haven't seen a dramatic change in overall grades that I can attribute directly to ICT, mainly because our use is so patchy." This contrasts with studies in better-resourced environments showing clearer links to achievement (Sotáková et al., 2020).

Negative impacts or concerns were also voiced. Distraction from non-academic content on personal devices was a concern for teachers and acknowledged by some students (Mutangi, 2024). More significantly, the issue of equity and the digital divide creating social stigma was raised by students in focus groups. One student (S12) shared, "It feels bad when the teacher shares notes on WhatsApp, and you don't have data to download them, or even a phone sometimes. Some students feel left out." This highlights how limited access can negatively impact participation and create social divisions within the class (Zvekuona, 2024). Concerns about the potential for increased plagiarism due to easy access to online information were also mentioned by teachers (Mutangi, 2024). Overall, while the potential positive impacts of ICT on engagement and understanding were recognized, the perception at Chipadze was that these benefits are significantly constrained by the low level of effective integration and the persistent barriers, with concerns about equity and distraction also present.

4.3.4 Research Question 4: What is the level of teacher preparedness for integrating technology in O' Level Chemistry at Chipadze High School?

The assessment indicated a generally moderate to low level of overall preparedness among the O' Level Chemistry teachers at Chipadze High School for effective ICT integration, marked by significant gaps particularly in pedagogical integration skills and confidence, despite some basic technological literacy.

In terms of technological competence, teachers generally reported familiarity with basic tools like smartphones, WhatsApp, internet searching, and standard office software (e.g., Word), aligning with findings by Chitsaka (2023). T1 stated, "I am comfortable using my phone, WhatsApp, and searching online. I can also use Word to type notes." However, confidence and competence significantly dropped when considering more specialized or pedagogically advanced applications. As previously noted, teachers expressed low confidence and lack of skill in using Chemistry-specific software, simulations, or virtual labs. This suggests that while basic digital literacy might exist, the specific technological skills required for enriching Chemistry instruction are often lacking (Dube, 2024).

The most significant gap appeared to be in pedagogical integration knowledge (TPACK). Teachers struggled to articulate how they would effectively design lessons incorporating ICT beyond basic presentation or communication. T2 admitted, "Even if we had the tools, knowing the best way to use a simulation to teach, say, chemical bonding, rather than just showing it, is something I need more training on. How do you structure the activity?" This indicates a lack of understanding of how to transform teaching practice using technology, rather than simply adding technology to existing methods (Mishra and Koehler, 2006; Tondeur et al., 2017).

Attitudes towards ICT integration were somewhat mixed but generally leaned towards acknowledging its potential value, tempered by frustration with existing barriers. T3 expressed a common sentiment: "I believe ICT could really help our students understand Chemistry better, especially the difficult topics. But with the lack of computers, reliable power, and proper training, it feels almost impossible to implement properly right now. It's discouraging." While outright resistance seemed less prevalent than in some studies involving older cohorts (e.g., Mutangi, 2024), a sense of resignation or feeling overwhelmed by the challenges was evident, negatively impacting proactive preparedness. Confidence levels were closely tied to perceived skills and the challenging environment; teachers felt less prepared and confident due to their skill gaps and the unreliable infrastructure (Pelgrum, 2017).

Teachers overwhelmingly identified inadequate professional development as a key factor contributing to their lack of preparedness. They reported either no specific training on integrating ICT into Chemistry teaching or participating in generic workshops that lacked subject relevance and practical application strategies (Dube, 2024; Abel et al., 2022). T1 stated, "We had a general computer literacy workshop once, but nothing on how to use technology specifically for teaching Chemistry effectively." There was a clear call for more targeted, practical, and sustained professional development focusing on pedagogical integration within their subject area.

In summary, while Chemistry teachers at Chipadze High School possess basic familiarity with common technologies and generally recognize the potential benefits of ICT, their overall preparedness for effective, pedagogically sound integration into O' Level Chemistry teaching appears limited, primarily due to significant gaps in specific technological skills, pedagogical integration knowledge, and confidence, exacerbated by inadequate training and challenging resource constraints.

4.4 Discussion of Findings

The findings presented above paint a picture of technology integration in O' Level Chemistry at Chipadze High School that is characterized by recognized potential, widespread challenges, and consequently, limited and inconsistent implementation impacting teacher preparedness and perceived student outcomes. These findings resonate strongly with much of the literature reviewed in Chapter 2, particularly studies conducted in similar resource-constrained, rural contexts within Zimbabwe and Sub-Saharan Africa, while also highlighting nuances specific to this case.

The limited range and frequency of ICT use documented at Chipadze, with heavy reliance on personal devices and basic applications like WhatsApp, starkly contrasts with the sophisticated integration possibilities (simulations, virtual labs, specialized software) discussed in the potential benefits literature (Hillmayr et al., 2020; Wushe, 2024). This reality directly corroborates findings from numerous Zimbabwean studies highlighting severe infrastructural deficits – lack of devices, power, internet, and technical support – as primary impediments (Chitsaka, 2023; Zvekuona, 2024; Mutangi, 2024; Dube, 2024). The situation at Chipadze underscores that national policy aspirations for ICT integration (MoPSE, 2019) often fail to translate into practical reality at the school level due to these persistent resource gaps, a disconnect also noted by Makuru and Jita (2022).

The identified barriers closely mirror those synthesized in Chapter 2. Lack of infrastructure stands out, aligning with Plomp et al. (2015) and numerous local studies. Crucially, the findings underscore the multifaceted nature of teacher-related barriers. The lack of technical skills aligns with Pelgrum (2017), but the perhaps more significant lack of pedagogical integration knowledge resonates strongly with the TPACK framework (Mishra and Koehler, 2006) and findings by Dube (2024), indicating that teachers need more than just technical proficiency. The mixed teacher attitudes, combining recognition of potential with frustration and sometimes resistance, reflect the interplay between perceived usefulness/ease of use (TAM) and the harsh realities of the teaching context (Hokonya, 2023; Abel et al., 2022; Chitsaka, 2023). The universal complaint about lack of time further validates findings by Becta (2004) and Chitsaka (2023). Institutional factors, especially the lack of technical and administrative support and restrictive policies, confirm the importance of an enabling school environment, often found lacking (Wushe, 2024; Zvekuona, 2024; Hokonya, 2023).

The mixed perceptions of ICT's impact at Chipadze are a logical consequence of the limited integration. While the potential for increased engagement and improved understanding, especially through visualization (Chigwenjere, 2024; Mutangi, 2024), is acknowledged (aligning with Ojha, 2016; Byusa et al., 2021), the practical constraints prevent these benefits from being fully realized or consistently observed. This explains the teachers' hesitancy to link current ICT use directly to improved academic performance, contrasting with studies from better-resourced settings (Sotáková et al., 2020). Importantly, the study confirms the negative ramifications highlighted by Zvekuona (2024) and Hokonya (2023) regarding the digital divide creating equity issues and social stigma within the student body, a critical factor often overlooked in purely technical discussions of integration. Student concerns about distraction and teacher concerns about plagiarism also reflect findings by Mutangi (2024).

Finally, the assessment of teacher preparedness confirms the central arguments of Chapter 2. The gap between basic digital literacy and the subject-specific pedagogical capacity needed for effective Chemistry integration (TPACK) is evident (Mishra and Koehler, 2006; Dube, 2024). The findings underscore the critical need for relevant, practical, and sustained professional development that goes beyond generic workshops to address Chemistry-specific pedagogical strategies using ICT (Wushe, 2024; Abel et al., 2022). Teacher confidence, a key element of preparedness, is clearly undermined by both skill deficits and the unsupportive resource environment, reflecting the principles of TAM (Hokonya, 2023).

In conclusion, the findings from Chipadze High School largely confirm the trends and challenges identified in the broader literature concerning ICT integration in resource-limited contexts. They highlight a significant gap between the potential of technology to enhance Chemistry education and the current reality, primarily driven by severe infrastructural limitations and deficits in comprehensive teacher preparedness (both technical and pedagogical). The study underscores the need for systemic interventions addressing resources, training, and supportive policies to enable Chemistry teachers at Chipadze to effectively integrate ICT.

4.5 Chapter Summary

This chapter presented and analysed the data collected through interviews and questionnaires aimed at assessing technology integration in O' Level Chemistry at Chipadze High School. The demographic profile of the teacher and student participants was outlined, confirming a reasonable response rate. Findings were presented in relation to the four key research questions. The analysis revealed a limited current use of ICT, primarily restricted to teachers' personal devices and basic applications like WhatsApp, with minimal utilisation of school resources or specialized Chemistry tools. A multitude of interconnected barriers were identified, prominently featuring inadequate infrastructure (devices, internet, electricity), significant gaps in teacher preparedness (skills, pedagogical knowledge, confidence, time), lack of institutional support (technical and administrative), and student equity issues related to the digital divide. Consequently, the perceived impact of ICT on student engagement and learning outcomes, while potentially positive, was reported as minimal and inconsistent due to the low level of effective integration. Teacher preparedness was assessed as generally low to moderate, particularly concerning pedagogical integration skills specific to Chemistry, highlighting critical training needs. The chapter concluded with a discussion interpreting these findings and linking them explicitly to the theoretical frameworks and existing literature reviewed in Chapter 2, confirming many previously identified challenges within the specific context of Chipadze High School. These findings form the basis for the conclusions and recommendations presented in the final chapter.

CHAPTER 5: SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Introduction

This final chapter of the dissertation brings together the core elements of the research, providing a comprehensive synthesis of the investigation into the assessment of technology integration in Ordinary Level Chemistry education at Chipadze High School. Building upon the problem setting in Chapter 1, the theoretical and empirical foundations reviewed in Chapter 2, the methodological approach detailed in Chapter 3, and the specific findings presented and analysed in Chapter 4, this chapter concludes the study. It will first present a concise summary of the research undertaking, highlighting its purpose, methodology, and key empirical outcomes. Subsequently, it will articulate the major conclusions drawn directly from these findings, addressing each of the research questions posed at the outset. These conclusions will then inform a set of practical recommendations tailored for various stakeholders involved in Chemistry education at Chipadze High School and potentially in similar contexts. Finally, recognizing that research is an ongoing process, the chapter will suggest potential avenues for future studies arising from the limitations and insights generated by this assessment.

5.2 Summary of the Study

The purpose of this study was to assess the current state of technology integration in the teaching and learning of Ordinary Level (O’ Level) Chemistry at Chipadze High School, examining the types of technology used, the barriers to effective integration, the perceived impact on student engagement and learning outcomes, and the level of teacher preparedness. The research was motivated by the increasing global and national emphasis on ICT integration in education, contrasted with potential implementation challenges, particularly in resource-constrained environments, and the specific demands of Chemistry as a subject.

The study adopted a qualitative-dominant mixed methods approach within a case study design focusing on Chipadze High School (Creswell, 2014; Yin, 2018; Jani, 2024). This design allowed for an in-depth assessment within the specific context of the school's Chemistry department. The study population comprised O’ Level Chemistry teachers and students, from which a purposive sample of four (4) Chemistry teachers and a stratified random sample of forty-five (45) O’ Level students were selected for participation (Kumar, 2018; Saunders et al., 2009). Data were collected using semi-structured interviews for teachers to gather detailed qualitative data on their experiences, challenges, and preparedness, and questionnaires for students, which included both closed-ended questions on technology use frequency, encountered tools, and attitudes, and open-ended questions for qualitative perspectives on opportunities and challenges. The analysis involved thematic analysis for the qualitative data from interviews and open-ended questionnaires to identify key themes and descriptive statistics (frequencies, percentages) for the quantitative questionnaire data to summarize trends in usage patterns, attitudes, and reported access. Trustworthiness and ethical conduct were diligently pursued throughout the research process through measures including informed consent, voluntary participation, confidentiality, anonymity, and detailed documentation.

The key findings of the study, as presented and analysed in Chapter 4, indicated that while learners and teachers at Chipadze High School are aware of ICT, the actual utilization in O' Level Chemistry is limited and inconsistent, primarily relying on personal smartphones and basic applications like WhatsApp for information access and communication rather than dedicated school resources or specialized Chemistry software. A multitude of interconnected barriers were identified as hindering effective integration, prominently including critical infrastructural deficits (insufficient functional devices, unreliable power, limited internet, lack of technical support), significant gaps in teacher preparedness (particularly in pedagogical integration skills and confidence, linked to inadequate, generic training), and institutional challenges (lack of targeted support and restrictive policies). Consequently, the perceived impact of current ICT integration practices on student engagement and learning outcomes, while acknowledged as having potential, was reported as minimal and inconsistent by both teachers and students due to the low level of effective implementation. Overall teacher preparedness was assessed as generally low to moderate, with a notable gap in the ability to integrate technology effectively into Chemistry-specific pedagogy, largely attributed to a lack of targeted professional development.

5.3 Conclusions

Based on the analysis of the data gathered from the teachers and students at Chipadze High School, the following conclusions are drawn in direct response to the research questions that guided this study. Firstly, in response to the first question, it is concluded that the types of educational technology consistently used for O' Level Chemistry learning at Chipadze High School are very limited. Primary utilization revolves around personal smartphones and basic communication platforms like WhatsApp for accessing shared notes and online lookups, and sporadic, teacher-led use of personal laptops or the few shared projectors for basic presentations or videos. Dedicated school computer labs are rarely accessible for Chemistry lessons, and specialized Chemistry software, simulations, or virtual lab platforms are essentially non-existent or unused.

Secondly, addressing the second research question, it is concluded that the most significant barriers to effective ICT integration in O’ Level Chemistry at Chipadze High School are multifaceted and interconnected. Critical limitations include severe infrastructural deficits (insufficient functional hardware, unreliable electricity, and limited, costly internet connectivity), a profound lack of targeted technical support and maintenance for available equipment, notable gaps in teacher preparedness encompassing both insufficient subject-specific pedagogical integration skills and a lack of confidence, exacerbated by inadequate professional development, institutional challenges regarding strategic prioritization and supportive policies, and student equity issues related to the digital divide.

Thirdly, concerning Research Question 3, it is concluded that while teachers and students at Chipadze High School perceive a strong potential for ICT to positively impact student engagement, motivation, and understanding (particularly through visualization and access to resources), the actual experienced impact of current ICT integration practices on overall student engagement and learning outcomes in O’ Level Chemistry is perceived as minimal, inconsistent, and largely unrealized. This gap between perceived potential and experienced impact is directly attributable to the low level of effective integration hindered by the pervasive barriers to access and consistent use. Furthermore, concerns were raised about potential negative impacts on equity, distraction, and academic integrity if challenges are not addressed.

Finally, drawing on insights related to preparedness from addressing the other questions, it is concluded that O’ Level Chemistry teachers at Chipadze High School demonstrate a generally moderate level of basic technological familiarity but a low level of overall preparedness for effective, pedagogically meaningful ICT integration specific to Chemistry. This lack of preparedness is characterized by significant gaps in subject-specific pedagogical integration knowledge and low confidence in utilizing complex or specialized tools, stemming primarily from a lack of adequate, targeted professional development opportunities and the demotivating effect of chronic resource limitations.

5.4 Recommendations

Based on the conclusions drawn from this assessment of technology integration in O’ Level Chemistry at Chipadze High School, the following recommendations are put forward for relevant stakeholders to address the identified challenges and enhance effective integration. Firstly, Chipadze High School administration should prioritize the strategic allocation of resources specifically towards enhancing ICT facilities for science departments, particularly Chemistry. This includes actively sourcing funding for dedicated, functional hardware (e.g., a small set of laptops for Chemistry class use), ensuring reliable electricity and internet access in science teaching spaces, and establishing a system for regular technical maintenance and support for ICT equipment. Furthermore, the administration should review and potentially revise school policies regarding the use of personal devices like smartphones to allow for regulated, teacher-supervised educational use in classes, acknowledging their current reliance by learners for accessing digital resources. Developing and implementing a clear school-wide plan for ICT integration across all subjects, with specific attention to resource allocation and support for science, is crucial.

In addition, chemistry teachers should actively seek and advocate for targeted professional development opportunities focused on pedagogical ICT integration in Chemistry, emphasizing the practical application of digital tools to teach specific Chemistry concepts effectively, including strategies for low-resource environments. This should involve learning how to leverage available tools (e.g., using smartphones for short videos, exploring offline simulation options if available, using basic presentation software creatively) for inquiry-based learning and visualization. Teachers should also collaborate and share strategies with colleagues on utilizing the limited available resources and effectively managing digital activities in classes, potentially forming a school-based learning community.

Furthermore, the Ministry of Primary and Secondary Education (MoPSE) and District Education Offices must increase targeted investment in ICT infrastructure and connectivity for rural schools like Chipadze, ensuring a baseline of functional hardware, reliable power, and affordable internet access specifically to support curriculum delivery, including science. They should also significantly enhance the quality and availability of teacher training programs for ICT integration, making them compulsory, practical, and subject-specific, equipping Chemistry teachers with the necessary TPACK for effective integration. Developing or curating accessible, curriculum-aligned digital resources for Chemistry, including simulations and digital content viewable offline, should be a priority. Establishing reliable technical support systems readily available to rural schools is essential for sustaining ICT initiatives.

Teacher Training Institutions (e.g., Bindura University of Science Education), must pre-service and in-service teacher training curricula in Science Education, particularly for Chemistry specialists, must incorporate rigorous training on pedagogical ICT integration relevant to diverse school contexts, including low-resource rural settings. This training should go beyond basic digital literacy to develop TPACK, equipping future teachers with the skills to design technology-enhanced Chemistry lessons using a variety of tools (including low-cost and offline options), troubleshoot common issues, and adapt their pedagogy to different levels of resource availability. NGOs and other stakeholders should align their support for education development in Zimbabwe with the specific needs identified in studies like this, focusing on sustainable interventions that address core infrastructural and resource gaps in rural schools' science departments (hardware, power, internet, relevant software, technical support). Partnerships should be developed with schools and communities to ensure support is needs-based, integrated into school plans, and contributes to long-term capacity building beyond initial donations.

5.5 Suggestions for Future Research

This study will provide valuable insights into the context of Chipadze High School and will reveal areas that will warrant further investigation to build a more comprehensive understanding of ICT integration in rural Chemistry education. Future researchers will conduct comparative case studies involving multiple urban secondary schools in different districts to explore whether the challenges, opportunities, and levels of preparedness identified at Chipadze will be common across a wider range of similar contexts, thereby enhancing the generalizability of the findings. In addition, a longitudinal intervention study will track the impact of a specific, targeted initiative—such as the provision of a dedicated set of laptops with offline chemistry simulations combined with teacher training on their pedagogical use—on student engagement, conceptual understanding, and academic performance in O’ Level Chemistry over a defined period in a rural school. This approach will allow researchers to observe how sustained access to technology and professional support influences learning outcomes over time. An in-depth qualitative evaluation will explore teachers’ and administrators’ perceptions and experiences regarding the implementation and effectiveness of ICT-related policies and support structures at the school or district level. By examining the lived experiences of educational stakeholders, this research will identify policy strengths and gaps that affect ICT adoption in rural settings. Further research will focus specifically on identifying and evaluating cost-effective and offline digital resources and pedagogical strategies for teaching particularly challenging O' Level Chemistry topics in contexts with limited internet connectivity and devices. This line of inquiry will aim to develop scalable solutions that can be adopted in similarly underserved schools.

Moreover, a socio-economic and home-environment analysis will examine the factors influencing out-of-school ICT access and use for chemistry learning within the Chipadze High School catchment area. By understanding the digital divide at the household level, researchers will be better positioned to design community-based support programs that target students' home learning environments. Finally, an investigation of student-led ICT initiatives—such as self-organized WhatsApp study groups and peer-to-peer resource sharing—will reveal how learners independently leverage technology despite school limitations. Insights from this research will inform strategies to support and amplify student-driven efforts, ultimately fostering more resilient and self-sufficient learning communities.

5.6 Chapter Summary

This chapter summarized the research study, detailing its purpose, methodology, and the key findings related to technology integration in O' Level Chemistry at Chipadze High School. The conclusions indicate that despite recognizing the potential of ICT for enhancing chemistry learning and holding positive attitudes towards it, learners and teachers face significant, interconnected barriers primarily linked to inadequate infrastructure, lack of resources, insufficient teacher preparedness (especially pedagogical skills), and institutional constraints. Consequently, the actual integration is limited, inconsistent, and not currently perceived as having a significant overall impact on academic performance, although potential benefits in specific instances are acknowledged. Based on these conclusions, a series of actionable recommendations were proposed for various stakeholders, including the school administration, teachers, government ministries, teacher training institutions, and NGOs, emphasizing the need for targeted investment in infrastructure, relevant teacher training, and supportive policies. Finally, avenues for future research were suggested to deepen the understanding and inform more effective strategies for bridging the digital divide and improving chemistry education through technology in rural Zimbabwean contexts.

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